OCTOBER 1959

Journal

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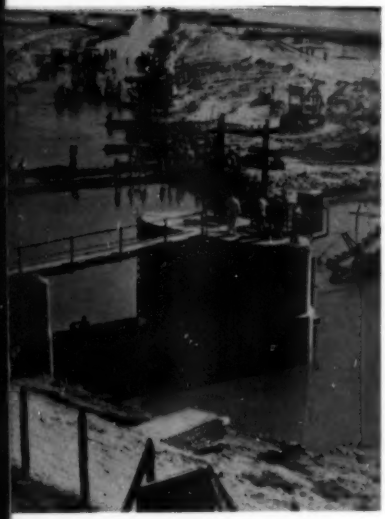
AMERICAN WATER WORKS ASSOCIATION



India's Jumna River which brought not only water but virus to Delhi

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Karalekas

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Piper

DEVELOPMENT OF RESOURCES
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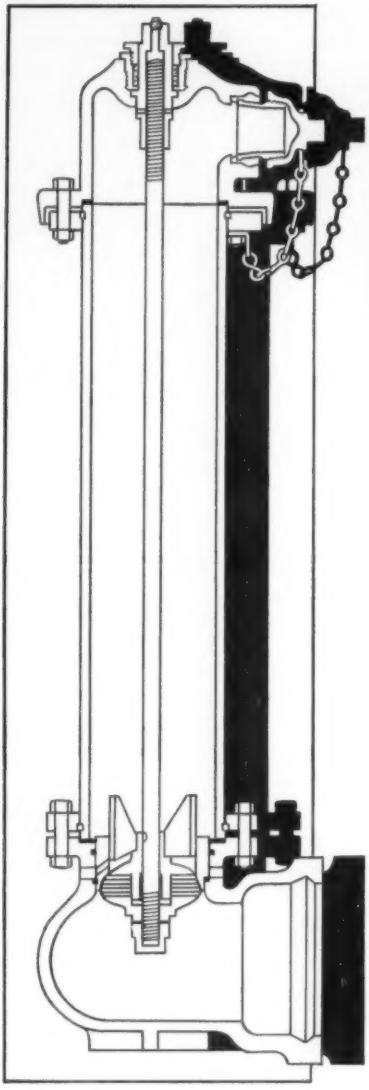

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Journal

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October 1959

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Coming Meetings

AWWA SECTIONS

Oct. 14–16—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

Oct. 18–21—Alabama-Mississippi Section (with Southwest Section) at Roosevelt Hotel, New Orleans, La. Secretary, Ernest Bryan, Southern Sales Mgr., McWane Cast Iron Pipe Co., Box 2601, Birmingham, Ala.

Oct. 18–21—Southwest Section (with Alabama-Mississippi Section) at Roosevelt Hotel, New Orleans, La. Secretary, L. A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 22–24—New Jersey Section, at Hotel Madison, Atlantic City. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Oct. 28–29—West Virginia Section, at Chancellor Hotel, Parkersburg. Secretary, Hugh W. Hetzer, Engr., Union Carbide Chemical Co., Box 8361, South Charleston.

Oct. 28–30—Ohio Section, at Biltmore Hotel, Dayton. Secretary, J. Howard Bass, M-C-G Co. Ltd., 4942 N. High St., Columbus.

Oct. 30—California Section (Business Meeting) at Hacienda Hotel, Bakersfield. Secretary, Roy E. Dodson Jr., Supt. of Production, San Diego Water Dept., Balboa Park, San Diego.

Nov. 4–6—Virginia Section, at Hotel Roanoke, Roanoke. Secretary, E. H. Ruehl, R. Stuart Royer & Assocs., 15 W. Cary St., Richmond.

Nov. 9–11—North Carolina Section, at Washington Duke Hotel, Durham. Secretary, D. Y. Brannock, Utilities Director, Burlington.

Nov. 15–19—Florida Section, at Hillsboro Hotel, Tampa. Secretary, J. G. Simmons, Plant Supt., West Palm Beach Water Dept., Box 1311, West Palm Beach.

Nov. 19–21—Cuban Section, Havana. Secretary, Juan Berasategui, Civ. Engr., Calle K, No. 303, Apdo. 22, Vedado, Havana.

(Continued on page 8)

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Coming Meetings

(Continued from page 6)

Spring 1960

Feb. 3–5—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, C. H. Canham, State Board of Health, 1330 W. Michigan St., Indianapolis.

Mar. 16–18—Illinois Section, at Pick-Congress Hotel, Chicago. Secretary, D. W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Mar. 17—New England Section, at Statler Hotel, Boston, Mass. Secretary, R. M. Soule, Assoc. San. Engr., State Dept. of Public Health, 511 State House, Boston, Mass.

Mar. 20–23—Southeastern Section, at De Soto Hotel, Savannah, Ga. Secretary, N. M. de Jarnette, Engr., Water Quality Div., State Dept. of Public Health, 309 State Office Bldg., Atlanta, Ga.

Mar. 23–24—West Virginia Section, at Hotel Pritchard (tentative), Huntington. Secretary, H. W. Hetzer, Engr., Union Carbide Chemical Co., Box 8361, South Charleston.

Apr. 5–7—New York Section, at New York Sheraton-Binghamton, Binghamton. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

Apr. 20–22—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, J. J. Rossbach Jr., Civ. Engr., Metropolitan Utilities Dist., 3906 N. 48th St., Omaha.

Apr. 20–22—Kansas Section, at Broadview Hotel, Emporia. Secretary, H. W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina.

Apr. 22—California Section, at Mark Thomas Inn, Monterey. Secretary, R. E. Dodson Jr., Supt. of Water, Dept. of Utilities, Balboa Park, San Diego.

Apr. 24–26—Canadian Section, at Statler Hotel, Buffalo, N.Y. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

Apr. 28–30—Montana Section, at Northern Hotel, Billings. Secretary, A. W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

May 4–6—Pacific Northwest Section, at Benson Hotel, Portland, Ore. Secretary, F. D. Jones, W. 2108 Maxwell Ave., Spokane 11, Wash.

OTHER ORGANIZATIONS

Oct. 12–15—Federation of Sewage & Industrial Wastes Assns., Statler Hilton Hotel, Dallas, Tex.

Oct. 19–23—APHA Annual Meeting, Convention Hall, Atlantic City, N.J.

Oct. 19–23—ASCE Annual Convention, Hotel Statler, Washington, D.C.

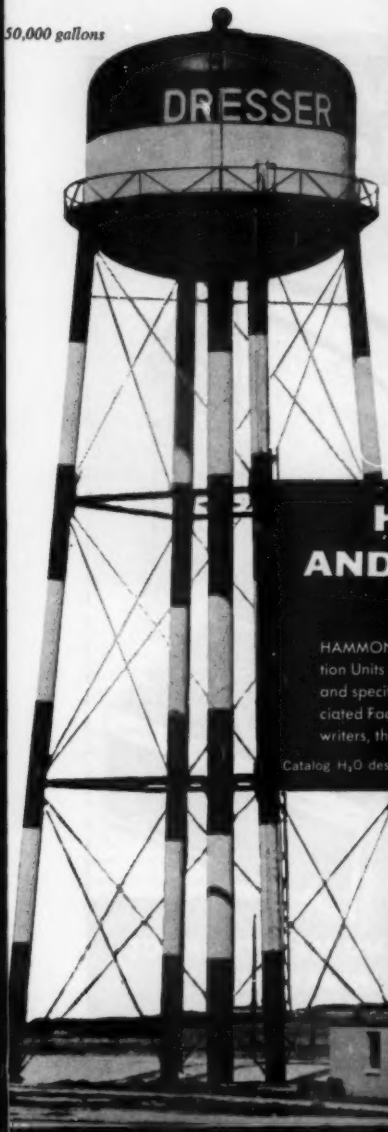
Oct. 20–22—ASA National Conference on Standards, Sheraton-Cadillac Hotel, Detroit, Mich.

Oct. 26–Nov. 6—Course on "Plankton Identification and Control," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Nov. 29–Dec. 4—ASME Annual Meeting, Chalfonte–Haddon Hall Hotel, Atlantic City, N.J.

Nov. 30–Dec. 4—Exposition of Chemical Industries, Coliseum, New York, N.Y.

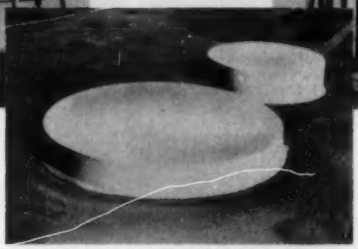
Nov. 30–Dec. 11—Course on "Chemical Analyses for Water Quality," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).



50,000 gallons

250,000 gallons

1,500,000 gallons



15,000,000 gallons (foreground) 10,000,000 gallons (background)

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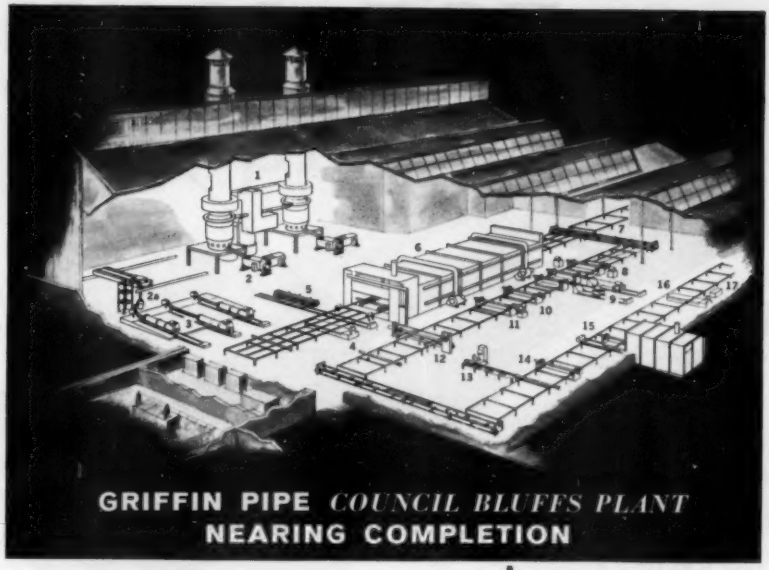

GRIFFIN PIPE *COUNCIL BLUFFS PLANT* NEARING COMPLETION

Cast iron pressure pipe users throughout the Mid-West will shortly *save time and money* on shipments and installations . . . because Griffin Pipe's new and automated production facilities are almost completed.

The Council Bluffs foundry—95,000 square feet of buildings on 19 acres of land, will be completed and in operation by the end of this year. Griffin-20 pipe joints will include patented Bell-Tite *"slip-on," mechanical,* and *bell and plain end.* The trademark "Griffin-20" refers to the length of the pipe—20 feet as opposed to conventional 16- and 18-foot lengths—in the complete 4-inch to 12-inch diameter size range. The modern 20-foot length means *10 percent fewer joints,* and lower installation costs!

The Delavaud process, employed at the Council Bluffs plant, involves centrifugal casting in a permanent, water-cooled, revolving steel mold. Iron cast in this manner, and subsequently annealed, is particularly strong, and has a controlled hardness that permits easy cutting and tapping in the field.

Griffin-20 cast iron pressure pipe will be manufactured in accordance with ASA, AWWA, and Federal Specifications for water and gas distribution.

Take advantage of the strategic location of this new plant . . . and the substantial economies it can effect in *your* pipe installations! Send for our brochure, "Introducing Griffin Pipe".

1. Griffin Hot Blast Cupolas
2. Holding Ladles
2a. Transfer Ladle
3. Delavaud Casting Machines
4. Weigh Scale
5. Transfer Car
6. Annealing Furnace
7. Pipe Transfer
8. Bell and Plain End Grinders
9. Reamers
10. Finish Grinding
11. Pipe Cut-Off Machine
12. Hydrostatic Test Press
13. Cement Liner
14. High Speed Wring-Out
15. Paint Booth
16. Weigh Scale
17. Pipe Stencils

GRIFFIN PIPE

DIVISION

GRIFFIN WHEEL COMPANY • COUNCIL BLUFFS, IOWA

GRIFFIN PIPE DIVISION COUNCIL BLUFFS

Griffin, founded in 1879 has 11 plants, and has poured more than 15 million tons of iron

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Macon, Ga.
Marcus Hook, Pa.
Menasha, Wis.
Middletown, O.
Monroe, La.
New Orleans, La.
Pine Bluff, Ark.
Port St. Joe, Fla.
San Francisco (Port Chicago), Calif.
Savannah, Ga.
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Vancouver, Wash.
Wisconsin Rapids, Wis.

the shortest distance between two points is usually the distance between our plant and you!

Check the list of General Chemical's dry or liquid alum producing locations at left. Chances are one is convenient and close to you. In addition to these plants, our chain of warehouses across the country makes stocks of dry aluminum sulfate readily available in every major center of commerce. Write or phone for information on how we can serve you.

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the problem...

The Problem: To lay three miles of 30" and 36" sewer along and under Three Mile Creek, all below the water table, without burdening the treatment plant with ground water.

The Engineer: J. B. Converse & Co., Inc., Mobile, Ala.

The Solution: Specifying concrete **water** pipe to AWWA Standard C302-57.

The Contractors: J. E. Milam Construction Co., Birmingham, Ala., Branch Erection Co., Mobile, Ala., Bernard & Byrd, Mobile, Ala.

The Result: To quote the Engineer, "We have found no leaks in the line and no measurable infiltration."

VULCAN MATERIALS COMPANY

CONCRETE PIPE DIVISION

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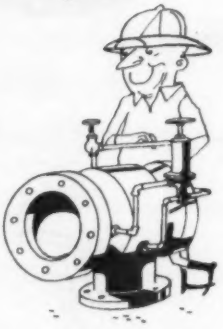
CUSHION THAT SURGE

G-A *Cushioned* Surge Relief Valve



A sudden surge of power can be disastrous, but such excessive pressure in your water lines is quickly relieved by the Golden-Anderson Surge Relief or Surge Arrestor Valve. The surge relief valve opens immediately when line pressure reaches pilot setting—the surge arrestor valve anticipates surge and opens on subnormal pressure to prevent surge.

Sizes 2½" to 36" Pressures up to 400 psi.

Write today for Technical Bulletins
Surge Relief—W2A
Surge Arrestor—W16

GOLDEN ANDERSON *Valve Specialty Company*

1221 RIDGE AVENUE, PITTSBURGH 33, PA.

Designers and Manufacturers of **VALVES FOR AUTOMATION**

Why General Filter is EVERYWHERE

Everywhere in the nation you'll find General Filter water and waste treatment equipment giving complete satisfaction to municipalities and industries. Here's why: **DEPENDABILITY** — the result of more than twenty years' experience in building quality water process equipment. **ECONOMY** — proved by long life and trouble-free operation of General Filter plants. **SERVICE** — by 45 sales offices and 36 field service departments coast-to-coast. There are many other reasons why it pays to specify General Filter. Write for complete information, bulletins and free estimates.

GENERAL FILTER CO.

WATER PROCESS EQUIPMENT AMES, IOWA

AERATORS • FILTERS • SOFTENERS • CLARIFIERS
FLASH MIXERS • FLOCCULATORS • PNEUMATIC CONTROLS
ROTARY DISTRIBUTORS • SLUDGE SCRAPERS

Across the Town... or Across Country

IT'S CONCRETE CYLINDER PRESSURE PIPE FOR MAINTENANCE-FREE WATER SYSTEMS

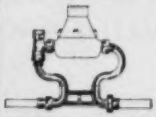
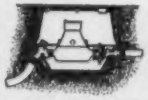
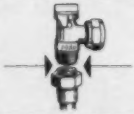
And pipelines requiring negligible maintenance mean money in the bank for your community. Whether repairs or replacements must be made on a remote supply line or a distribution line in the middle of town, heavy expenditure is involved.

Cut these expenses to the bone by using CONCRETE CYLINDER PRESSURE PIPE, whose unexcelled performance record is a product of the strength of steel joined with the durability of concrete.

Further, this pipe is low in first cost, economical to install, easy to tap under pressure, and will retain its initial high carrying capacity throughout its exceptionally long, trouble-free life. Call on your nearest supplier of Concrete Cylinder Pressure Pipe for the utmost in dependable, economical pipelines.

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 N. LA SALLE STREET • CHICAGO 1, ILLINOIS

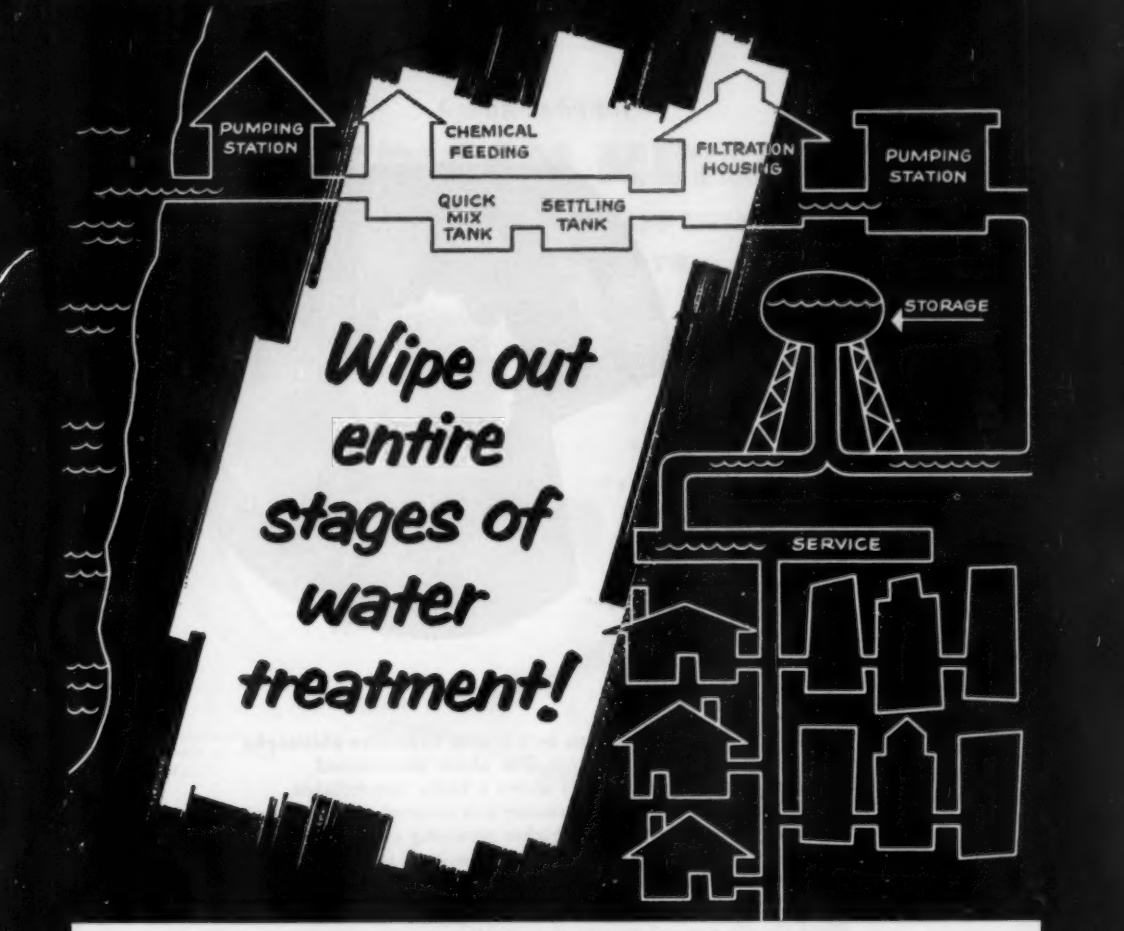
Why it is PROFITABLE to use FORD products

Meter men know their settings		**1. You Standardize Your Settings** Regardless of the model, Ford yokes and setters provide standard, permanently aligned settings. No time lost trying to "rassle" around with the odd ones.
	Keep your meters on the level	**2. You Set Meters Horizontally** No matter how the water line runs—horizontally, vertically, in a corner or diagonally, Ford settings keep your meters level for most efficient operation.
Change a meter in a few moments		**3. You save on Meter Changes** Meters set in Ford yokes or setters may be removed and replaced quickly and economically. The time saved on one meter change may more than pay for the setting.
	50 years or more in one place	**4. Inside or Outside - Settings are Permanent** Whether you have basement or outside meters Ford settings are good for the life of the service.
Do you use shallow settings?		**5. Adaptations for Every Climate** Ford shows you how to get the best settings for your climate—and provides all the equipment, even to meter boxes, barrels, forms and covers.
	Be sure you are paid enough	**6. Complete Testing Equipment** Ford bench or portable testing equipment helps you keep meters operating efficiently so that you get paid for all the water you deliver.
You get the breaks on new inventions		**7. Ford Research Keeps You Out in Front** For over 60 years Ford has specialized in developing and producing better equipment for setting and testing water meters. Stay "out in front" with Ford.

FOR BETTER WATER SERVICES

FORD

THE FORD METER BOX COMPANY, INC.
WABASH, INDIANA



Wipe out entire stages of water treatment!

A complete Celite diatomite filtration system can eliminate the costs of conventional pre-treatment facilities

Now you can do something about skyrocketing per capita water consumption costs—as are dozens of municipalities every year. And get clearer, sparkling-bright water in the bargain!

Install one of today's small compact diatomite filtration plants, using Celite* filter aids. In many cases, raw water can be filtered directly, eliminating several of the costly conventional pretreatment stages—flocculation, quick-mixing tanks, and settling tanks, for example.

Result†: Filtration plants requiring only ¼ the space of sand plants of equal capacity. Capital costs cut almost in half—savings of up to 45%.

Here's why. Celite diatomite filters better than any other medium. Every cubic inch of the skeletal diatomite particles contains millions of microscopic filter pores. These are so minute they remove all suspended solids, including amoebae and algae, without flocculation.

Mined by Johns-Manville from the world's purest commercially available diatomite deposit, Celite is carefully processed for uniformity. You have a wide choice of grades for best balance of clarity and flow rate. For further information, call your nearby J-M Celite engineer. Write direct for free technical reprints and illustrated brochure. Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

* Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

† See *Comparison Studies of Diatomite and Sand Filtration* by G. R. Bell, Journal American Water Works Association, September, 1956, or write for free reprint.

JOHNS-MANVILLE JM

here's what "out of sight out of mind" does to a water main

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafl., Lima, Peru

AMERICAN METERS

HAVE WHAT THE WATER SUPERINTENDENT WANTS

American Frost Bottom Meter

QUALITY that includes

- **WORKMANSHIP**
- **DURABILITY**
- **ACCURACY**

Everyone claims quality . . . finest quality . . . best quality — but like the pudding that is proven in the eating — so the proof of quality in a meter is in the running. This establishes its accuracy, and in continued running for long periods of time, its durability.

Judged on that basis, AMERICAN METERS are unsurpassed! For in operation, the fine workmanship, the excellence of manufacture of AMERICAN METERS are clearly demonstrated. AMERICAN METERS today are built to exceed the accuracy and life of meters built 35 years ago, that are still giving dependable accurate service. Yes truly, AMERICAN is a QUALITY WATER METER.

- *Quality Control at each manufacturing step insures the accuracy and reliability of American Meters.*

BUFFALO METER COMPANY
INCORPORATED

2914 Main Street
Buffalo 14, New York

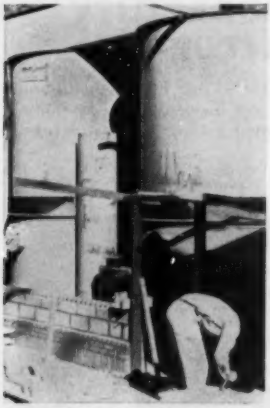
FLUIDICS

is a Pfaudler Permutit program providing the know-how, the equipment, and the experience for solving problems involving fluids

FLUIDICS covers such varied phases of fluid handling and control as:

corrosioneering
water treatment
waste treatment
fluid analysis
agitation
blending
metering
valving
flow rate control
piping
storing
heat transfer
pumping

Whenever you have a fluid-handling problem, put the Pfaudler Permutit FLUIDICS program to work.



Automatic valveless filters, like this tandem setup photographed during its installation at an Eastern municipality, are now in service.

Permutit valveless filter, municipal design

FLUIDICS AT WORK

The only filter that works by itself

We sell most of our Permutit valveless filters simply by pointing out the things you *don't* have to do and the things you *don't* need once you install one:

Manpower — None needed. No valves to operate, gauges to watch, pumps to start or stop, or decisions to be made.

Valves — None. Entire operation is automatic and hydraulic.

Pumps — None needed. All work done by atmospheric pressure.

Rotary wash — None needed. Unit operates only to four- or five-foot head . . . schmutzdecke cannot become packed enough to need breaking up.

Flow controller — No mechanical, pneumatic, or hydraulic devices needed . . . unit filters whatever volume you deliver.

Maintenance — None, outside of normal, routine painting. No moving parts to wear out.

The best part of our story is the fact that this filter costs less than conventional gravity filters, either manual or automatic.

The basic laws of hydraulics behind this filter's design show in the diagrams. If you're rusty on your hydraulics, or are just plain interested, we invite you to write for our bulletin on valveless filters.

Address yourself to our Permutit Division, Department JA-109, 50 West 44th Street, New York 36, New York.

PFAUDLER PERMUTIT, INC.

Specialists in FLUIDICS . . . the science of fluid processes

What's this talk about

PACKAGED WATERLINES?

It's about a brand new way
to save money.
It means pipe to your specifications;
cut exactly–no random lengths;
lined, coated and delivered–
or scheduled deliveries
according to your needs.
There are even standard sizes
available from stock.
Seems that Southern Pipe
can do everything
from pipe production
and processing
to trenchsite delivery.
For us customers
it means one P.O.
Less red tape and worries,
and lower costs.
I buy
from Southern Pipe.
(Maybe you should, too.)

Write for brochure on products, services and facilities.

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DIVISION OF U.S. INDUSTRIES, INC.
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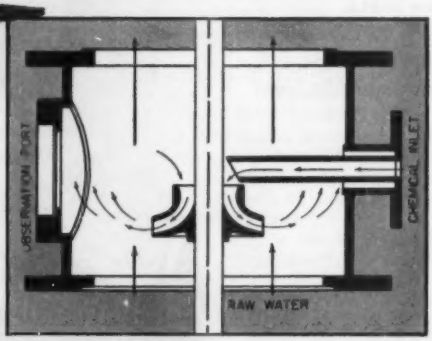
COMPLETE..VIOLENT..INSTANT..UNIFORM

American HOMOMIX CHEMICAL MIXING without a Mixing Tank

2-stage Homomix

The HOMOMIX gives instantaneous, violent, and uniform mixing of one or more chemicals, or gases, with water. *Immediate, total diffusion*—the most important factor for the efficient and economical addition of chemicals or gases—is obtained *without the use of a mixing tank!* For new plants it eliminates the necessity for costly mixing tank construction; for existing plants it can be effectively used to improve treatment.

The HOMOMIX, in one or more stages, is installed in, and forms part of, the piping. Diffuser impellers rotate in blending chambers and discharge directly across the flowing-through stream. Each chamber has one or more chemical inlet connections and a transparent plastic observation port through which the mixing action is visible. A lifting stage can be provided for additional head, if required. *Write for Technical Supplement HM and Bulletin 300.*



Our staff of Sanitary Engineers will cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

AMERICAN WELL WORKS

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112 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

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MUELLER®

SERVICE CLAMPS

fast, permanent connections to any main

Tough, malleable iron body is accurately contoured to fit pipe and is heavily galvanized.

Precision machined, full length threads.

Unusually large cross sectional area for maximum strength.

Rolled steel, cadmium plated nuts use National Standard threads for precise fit.

Regularly furnished, neoprene gasket is cemented in recess in body. Lead ring gasket available.

SERVICE CLAMP

Mueller or Iron Pipe thread tapping
Tapping sizes from ¾" through 2"
Pipe sizes from 1" through 12"
Single or double strap type

Flattened, forged steel, cadmium plated straps are accurately curved to fit pipe and give maximum bearing and stability.

These features are typical of the attention to detail in research, design and engineering that becomes a part of every Mueller product manufactured for the water industry. Write for complete information.

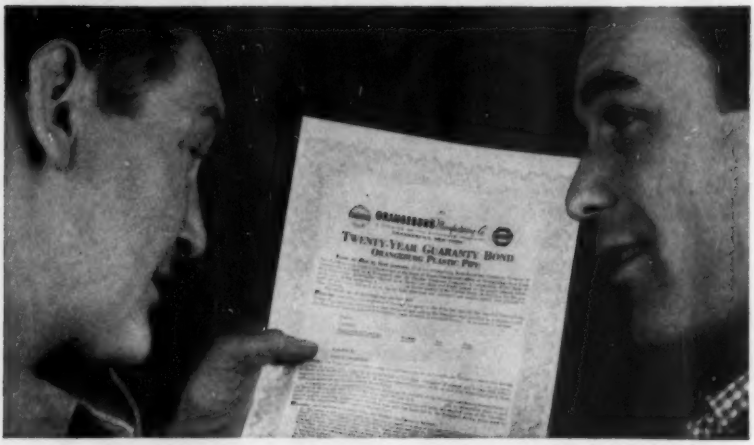
All Mueller Service Clamps now packed in labeled, corrugated cartons for ease in handling, shipping and storing.

MUELLER CO. **DECATUR, ILL.**

Factories at: Decatur, Chattanooga, Los Angeles
In Canada: Mueller, Limited; Sarnia, Ontario

3699 — Water ad; Journal of AWWA, Municipals — October, 1959.

Now you can tell customers **"...the plastic pipe on this job is guaranteed and bonded for 20 years!"**



It's ORANGEBURG® *SP*® *Plastic Pipe*

What a selling point! Tell your customer you use *slit-proof* Orangeburg *SP*—the *only* plastic pipe Guaranteed and Bonded for 20 years for cold water service. Tell him, too, the Bond will be made out in *his* name as written evidence you have used the finest-quality plastic pipe available.

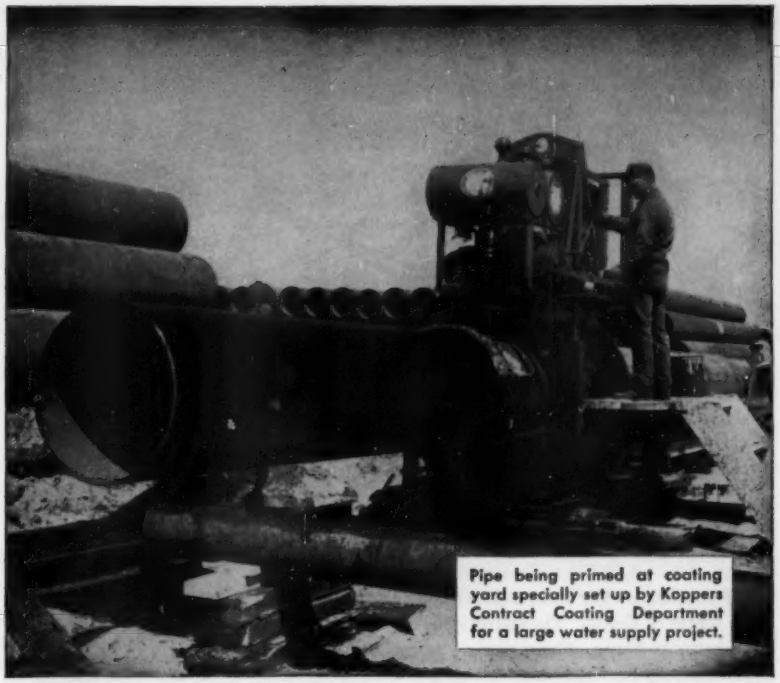
Under terms of Bond, repairs or replacements, INCLUDING LABOR COSTS, *due to failure of pipe will be made at Orangeburg's expense. You can't lose.*

And it's easy to apply for the Bond. When Orangeburg *SP* installation is completed, send *"Request for Bond"* Form to Orangeburg. After approval, Bond is sent direct to your customer.

Be first to cash-in with Orangeburg *SP* Plastic Pipe and the exclusive iron-clad 20-year Guaranty Bond offer. See your Authorized Orangeburg Wholesaler or write Dept. JA-109.

Approved for drinking water by National Sanitation Foundation NSF LIFE

ORANGEBURG MANUFACTURING CO. • Orangeburg, N. Y. • Newark, Calif.
A Division of The Flintkote Company, Manufacturers of America's Broadest Line of Building Products



Pipe being primed at coating yard specially set up by Koppers Contract Coating Department for a large water supply project.

3/32" MAKES ALL THE DIFFERENCE

Steel water pipe will last much longer underground with the armor-like protection which a 3/32" coating of Bitumastic 70-B AWWA Enamel gives it. This corrosion-preventive coating is vital to the long-life of water lines.

Bitumastic Enamel has helped steel water lines set high flow capacity records of 40 years and more. Proven performance is one reason why so many water supply engineers are specifying steel pipe, lined and coated with Bitumastic 70-B AWWA Enamel, for their projects today. A lining of this enamel gives a uniformly smooth inside surface that has proved to have the highest flow coefficient available.

You can obtain more information about the economies of Bitumastic 70-B enameled steel pipe from Koppers Company, Inc., Tar Products Division, Dept. 110H, Pittsburgh 19, Pennsylvania.

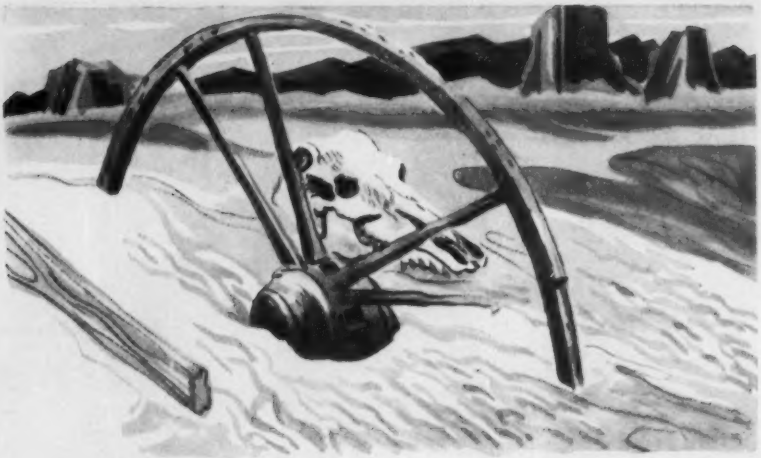
KOPPERS

ONLY KOPPERS MAKES

BITUMASTIC

REG. U. S. PAT. OFF.

ENAMELS

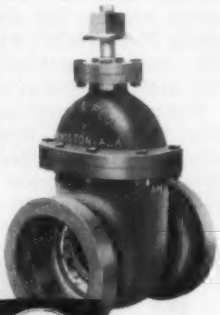


DEATH in the DESERT

If you have ever seen a desert or picture of a desert, you realize it is a scene of death. There may lie the bleached bones of an animal or a human being. There are no trees, no vegetation. The soil may be rich in plant food, but nothing grows. It is proof that water is the lifeblood of everything that grows—animal or vegetable.

It is an historic fact that past civilizations have risen and fallen according to their ability to satisfy their need for water. Water's abundance in America in the past is now deceiving. Not that the U. S. is turning into an arid desert, but the problem is inadequate water distribution facilities. U. S. water works improvements have not kept step with the phenomenal increase in population and industrial expansion, which means increased demand for water.

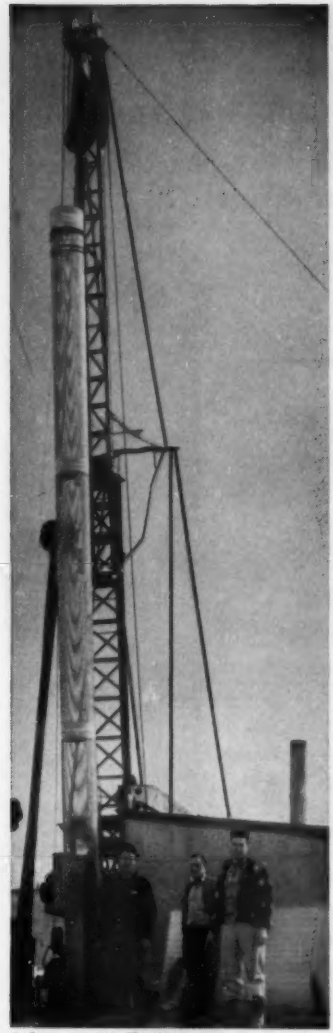
U. S. water works officials know this situation and are trying to solve it, but they need better public support.



This Series is an attempt to put into words some appreciation of the water works men of the United States.

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF W WALWORTH



Johnson Well Screen of Everdur being lowered into the new 4-mgd well at Plymouth, Mich.

Big screen of EVERDUR serves new 4,000,000-gallon well in Plymouth, Mich.

In developing a new source of water to meet growing community needs, Plymouth, Mich., more than doubled the capacity of its water system with a single well capable of providing 4,032,000 gallons per day.

The new well is 110 feet deep, has an 18-inch casing, and a Johnson Everdur Well Screen 16¼" in diameter by 32', 1½" long. Edward E. Johnson, Inc., St. Paul, Minn., fabricates tough, corrosion-resistant well screens from specially shaped Everdur wire and rod by a unique automatic welding method. Johnson welded Everdur screens have proved their durability by years of service in large-capacity wells.

• **Everdur* resists corrosion.** Sewage-treatment and waterworks equipment of Everdur has been in service without replacement for 20 years and longer.

• **Everdur is tough.** Everdur also possesses high mechanical strength and resistance to wear and abrasion—so that engineers can design light-weight, wrought-metal equipment.

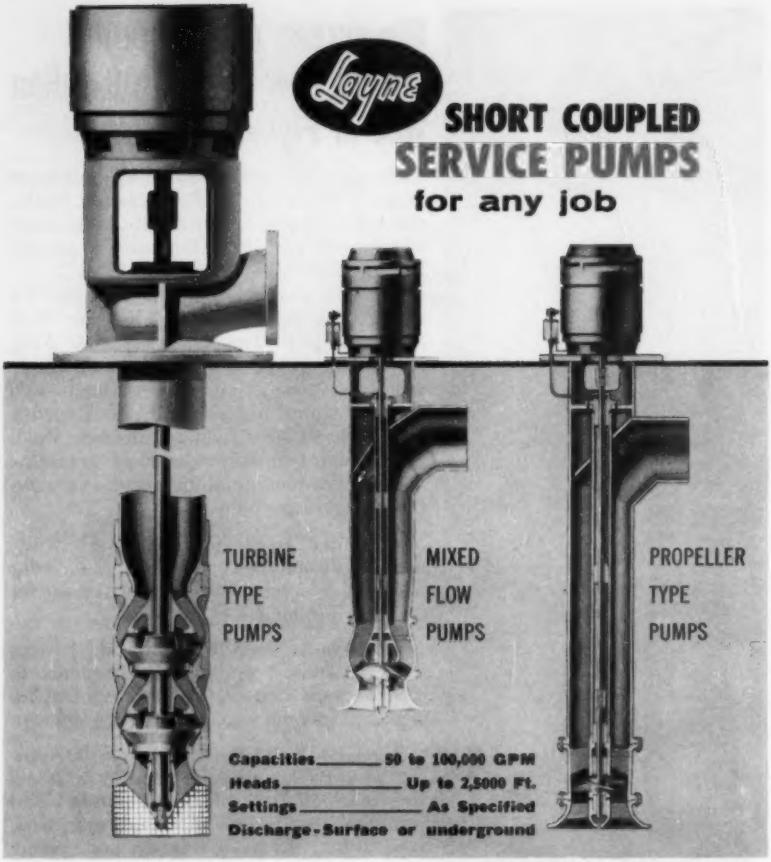
• **Everdur is readily fabricated.** Alloys are available for hot or cold working, welding, free machining, forging, and casting—and can be obtained in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

• **Write for Publication E-11,** "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment"—or for technical help in selecting the correct material for your job. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

*Reg. U. S. Pat. Off.

57132

EVERDUR Anaconda's Family of Copper-Silicon Alloys
MADE BY THE AMERICAN BRASS COMPANY
STRONG • WORKABLE • WELDABLE • CORROSION-RESISTANT



Top performance, high efficiency and less maintenance are factors which influence the selection of a short coupled pump. Layne Vertical Service Pumps fulfiill these requirements and offer the advantages of lower installation and operation costs, low submergence requirements, simple alignment, no priming and less floor space demands. For any short coupled pumping job . . . specify Layne.

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LAYNE TURBINE TYPE SERVICE PUMPS—NO. 300
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Atlanta, Georgia: This 8200′ extension of the existing water supply main system was laid by Arthur Pew Construction Co. of Atlanta. The line is Dresser-Coupled throughout.

Two man-minutes per bolt make every Dresser Coupling a permanent, bottle-tight joint.

Expansion's no problem

with Dresser-Coupled Pipelines

It's easy to install a Dresser-Coupled steel waterline. There's no need for expensive, specialized equipment and labor; and installation is so rapid that the line is often fully laid immediately behind the trencher. Ordinary labor can make permanent, bottle-tight joints in a matter of two man-minutes per bolt. The joints will last the life of the line.

And Dresser® Couplings protect the line, too. These non-rigid couplings absorb vibration, stresses of expansion and contraction, shocks and pressures of shifting or settling earth. They allow up to 4° of pipe deflection at every joint, and joints are made with plain end pipe. Why not figure your next water line with Dresser Couplings? You can figure your costs *accurately* . . . and consistently *lower!*

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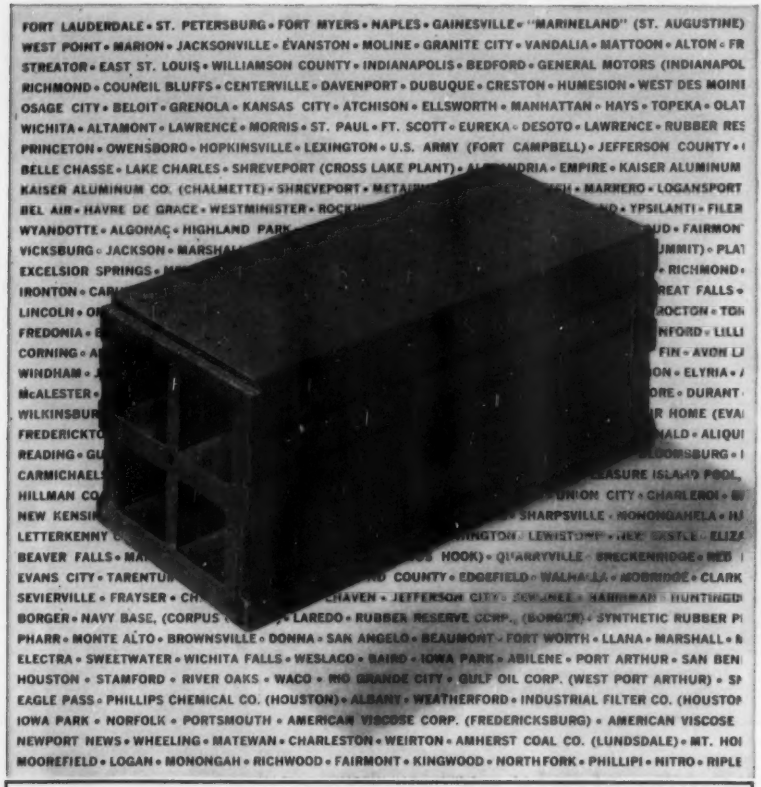
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For Two More Filter Plants

BALTIMORE AGAIN CHOOSES LEOPOLD

All three of Baltimore's filter plants will be outfitted with Leopold Glazed Tile Filter Bottoms when present construction is completed later this year.

Leopold bottoms were chosen for Montebello plants #1 and #2 following their proven performance in the 120 M.G.D. Ashburton plant, where they were installed in 1956. The three plants will have a combined capacity of 360 M.G.D.

Made of de-aired fire clay—vitrified and salt glazed, the Leopold filter bottom can't be matched for dependable, economic service. Individual Leopold blocks can't corrode or absorb water . . . are acid and alkali resistant . . . not subject to tuberculation . . . provide equal filtration and uniform wash distribution. For modernization or new construction, consider the long term economy and performance offered only by Leopold filter bottoms. Write today for complete information.

F. B. LEOPOLD CO., INC.
ZELIENOPLE, PA.
Exclusive Canadian Representative: W. J. Westaway Co., Ltd. Hamilton, Ontario

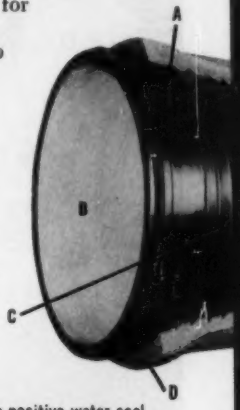
Leopold

GLAZED TILE FILTER BOTTOMS

AMERICAN CONCRETE CYLINDER PIPE *provides...*

DEPENDABILITY with ECONOMY

This pretensioned concrete cylinder pipe embodies all of the qualities and characteristics sought by water works engineers for permanent water supply and transmission lines – strength, sustained high carrying capacity; trouble free service and unusually long life. When you select pressure pipe for your permanent water "growth lines," be sure to investigate American Concrete Cylinder Pipe, a superior product with an outstanding record of acceptance.



A. The steel cylinder provides a positive water seal or membrane as well as part of the total steel area required for internal stresses.

B. The smooth centrifugally applied mortar lining of a nominal ¾" thickness provides positive internal protection, sustained hydraulic capacity, and, **imparts rigidity and strength through "arching effect."**

C. Steel reinforcement rods, which together with the steel cylinder provide the total cross-sectional steel area required for the operating pressure specified, are wound under controlled tension and accurate spacing around the concrete lined cylinder, placing it under moderate compression.

D. In conjunction with the steel rod reinforcement along the entire surface of the cylinder, the application of a dense concrete coating produces, in effect, a **reinforced jacket** which affords additional structural strength as well as positive exterior protection.

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IS LIKE A SERIES OF BODY PUNCHES!

Little by little it "softens up" a pump discharge line for the final knock-out. Moderate slamming causes leakage, throws pipes out of line or causes other damage that may go undiscovered for years. Heavy slamming often causes serious damage and service interruption.

Why risk trouble and service loss? Ludlow and Rensselaer List 340 non-slamming check valves *are non-slamming under the most severe conditions,* thanks to adjustable spring tension. They are recommended as standard equipment wherever slamming is likely to occur.

WRITE TODAY for L&R Check Valves Catalog, showing 3" to 30" sizes, with or without lever arm and spring. All materials and workmanship exceed the A.W.W.A. requirements for gate valves and fire hydrants.

POSITIVE CONTROL OF AIR INLET OR DISCHARGE is afforded by Ludlow or Rensselaer air and vacuum and air release valves.

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VALVES AND HYDRANTS

THE LUDLOW VALVE MANUFACTURING CO., INC., TROY, N. Y. – SINCE 1861

K·M ASBESTOS-CEMENT PRESSURE PIPE

Exclusive, patented FLUID-TITE Coupling connects in only two easy steps!

Streamline installation . . . reduce costs and time with modern "K&M" Asbestos-Cement Pressure Pipe.

To connect pipe to FLUID-TITE Coupling, just lubricate the rubber gasket—and slide the pipe in. Lay more pipe per hour than ever before, and do it under all soil and weather conditions.

Tough, hardy "K&M" Asbestos-Cement Pressure Pipe firmly holds down pumping costs and maintenance costs. Won't corrode or tuberculate, and is completely immune to electrolysis. Permanently sealed joints remain root-tight and water-tight always.

What makes "K&M" Asbestos-Cement Pressure Pipe so special? Eighty-five years of asbestos engineering by one of America's pioneers in asbestos products. Put this wealth of experience to work for you. Write to us today.

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FLUIDICS AT WORK

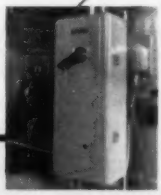
SIMPLEX know-how automates wash cycle at Mt. Clemens, Mich.

No need to walk back to the panel—table contains Simplex remote control station to set wash cycle into operation, either automatically or manually.

Easy to read from any point in the filter gallery—big 24-inch dial Simplex wash water gauge with automatic indicator light to show status of pump operation.

The heart of this fully interlocked system is the Simplex master control which translates information into an automated operation of the wash cycle at this recently enlarged Mt. Clemens filter plant.

To maintain desired rate—magnetic reversing motor starter automatically positions butterfly valve.



Acts on signal from panel—magnetic starter automatically sets wash water pump in operation.

Wash water pump furnishes continuous flow.

Controls rate automatically—butterfly valve is electrically operated for instantaneous response to panel controls.

SIMPLEX®

a division of PFAUDLER PERMUTIT INC.
Lancaster, Pennsylvania

Specialists in FLUIDICS . . .
the science of fluid processes

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to move an ocean–

by the bucketful is all right for this Sunday engineer, but for full time, 24-hour transfer of millions of gallons of water, rugged Peerless Hydro-Foil Pumps are the answer. Steam generation plants, sewage disposal plants, large irrigation and drainage projects, flood control stations and many other rigorous duties are being handled efficiently, dependably and economically by these giants of the pumping world. Available as either propeller type or mixed flow type, Peerless Hydro-Foil pumps have proved themselves to be the finest from every standpoint. For the big jobs, get the big pump, get the Peerless Hydro-Foil!

WRITE FOR ILLUSTRATED BULLETIN NO. B-148

PEERLESS PUMP

Putting Ideas to Work

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FOOD MACHINERY AND CHEMICAL CORPORATION

Peerless Pump Division

Plants: LOS ANGELES 31, CALIFORNIA and INDIANAPOLIS 8, INDIANA

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"bottle" tight —Require no special coatings to prevent cracking, leaking.

uniform —Always "measure up" to specified standards for predictable performance.

durable —Meet any combination of stresses better than any material of equal mass. Ductile to withstand more abuse.

flexible —Steel tanks can be readily pre-designed and engineered to meet the most specific conditions.

specified in AWWA standards — Only *steel* tanks are so specified.

For unparalleled protection . . . always specify STEEL

STEEL PLATE FABRICATORS ASSOCIATION

STEEL PLATE FABRICATORS ASSOCIATION
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Alexander Orr, Jr. Water Treatment Plant
DEPARTMENT of WATER and SEWERS
CITY of MIAMI, FLORIDA

Design and Supervising Engineers
DEPARTMENT OF WATER AND SEWERS,
CITY OF MIAMI
Contractor
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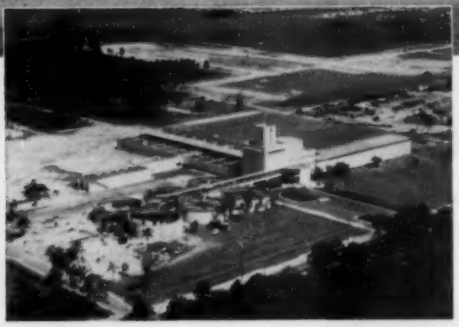
Modern, excellently designed exterior complements the highly efficient facilities at the Orr plant.



Aerial view shows the extensive layout required to treat water from the high capacity wells in the Everglades and at plant site.

ONE SOURCE
ONE RESPONSIBILITY

Modern Builders Filter Control Tables centralize individual filter operation . . . display output and head loss data . . . allow remote operation of the large hydraulically-operated Builders Butterfly Valves used for washing, draining and operating filters.

Omega Fluoride Feeder au
matically feeds exact Sodi
Silico-fluoride requirement
to water after recarbonat
in response to signals sent
feeder from Builders Vent
meter that measures in
flows to plant.

Providing Pure Water for the Magic City...

INTEGRATED CONTROL EQUIPMENT FURNISHED BY SINGLE, RESPONSIBLE SOURCE!

B-I-F equipment controls 100 MGD capacity at Miami's new Alexander Orr, Jr. Water Treatment Plant.

A vital part of the greater Miami water system, the modern Orr treatment plant is a complex operation where complete integration of all control equipment provides maximum operational efficiencies, economies, and reliability.

B-I-F Industries, single, responsible supplier of all supervisory control, filter control, chemical feeding and related equipment, brought immediate and long term savings in both time and money. How? By providing better coordinating of efforts during the planning, installation and start-up stages of the project. For full particulars, contact any one of B-I-F's nationwide sales and service offices, or write . . .

B-I-F Industries, Inc., 365 Harris Ave., Providence, Rhode Island.

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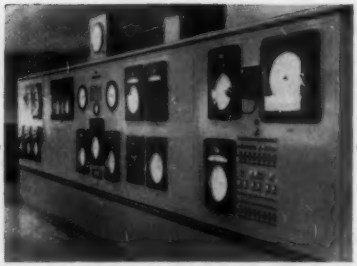
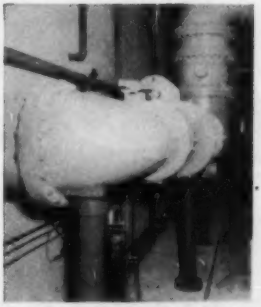
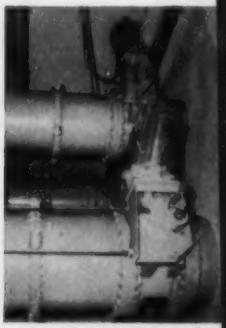


Builders Master Control Panel serves as centralized information center for operating entire plant. Panel provides supervisory control of well field, indicates all flows entering and leaving plant, indicates amount of chemicals being fed, and pressures both at plant and in downtown area.



Builders Rate-of-Flow Controller and Diaphragm Pendulum Unit provide simple, rapid rate-of-flow setting for economical filter operation. Self-actuated, these durable units conserve head, assure accurate flow control.



Compact Builders rubber-lined AWWA Butterfly Valves are equipped for both automatic and manual emergency operation . . . have many exclusive design features for efficient "bubble-tight" operation.

TRINITY VALLEY

For All Cast Iron Water Works Fittings

AWWA Standard Bell Spigot Watermain Fittings—2" through 36".

Ring Tite Fittings 3" through 16" Class 150. Class 100 through 12".

Short Body and Mechanical Joint Watermain Fittings—2" through 20".

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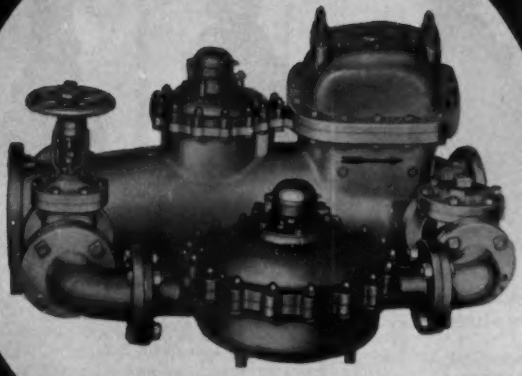
TRINITY VALLEY IRON AND STEEL COMPANY

Phone PE 8-1925 Fort Worth, Texas P. O. Box 664

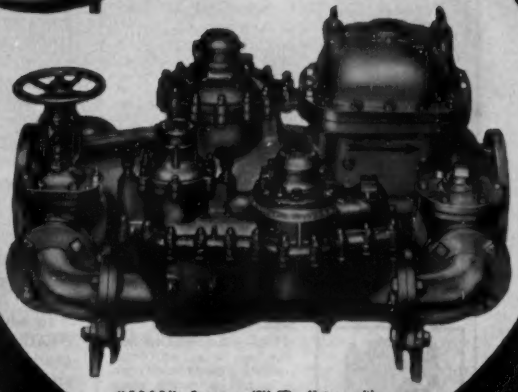
HERSEY

DETECTOR (Fire Service) METERS

Are available in Two Types — shown below



HERSEY Detector Meter with Disc Meter on By-Pass



HERSEY Detector (FM-CT) Meter with All-Bronze Compound Meter on By-Pass

For your own protection it is wise to install

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Detector (Fire Service) Meters on all industrial fire service lines

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YOU CAN'T BUY A BETTER WATER METER THAN HERSEY

KENNEDY VALVE has a complete line of A.W.W.A. Standard Gate Valves . . .

. . . that conform to A.W.W.A. specifications in all respects

FIG. 56
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Bell Ends

FIG. 57IX
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Mechanical Joint Ends

FIG. 561
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Flanged Ends

FIG. 566
- Outside-Screw-and-Yoke
- Rising Stem
- Parallel Seats
- Flanged Ends

Construction features . . .

Conventional stuffing box
with adjustable gland has ample space for packing that conforms to Federal specification HH-P-106c. The bottom face of the stuffing box flange is faced smooth to form bearing surface for stem thrust collar.

O-Ring seals
once installed no adjustment of any kind is required. The top O-Ring is the dirt seal and the bottom O-Ring is the pressure seal.

Operating nut
is Higher Strength Cast Iron. The base flange, with arrow indicating direction to open, is shaped to permit access from ground surface to adjust gland nuts with an extension socket wrench.

KENNEDY A.W.W.A. Standard gate valves are designed specifically for use in water works systems. Conforming to A.W.W.A. Specifications, in several particulars these valves exceed these standards of strength and refinements of design.

While A.W.W.A. Specifications cover only bell end and flanged end non-rising stem valves, the KENNEDY line also includes outside-screw-and-yoke valves and a wide variety of pipe connections including: Bell Ends, Flanged Ends, Mechanical Joint Ends, Universal Pipe Ends, Asbestos Cement Pipe Ends, Screwed Ends, Ring-Tite Pipe Ends and Spigot Ends.

In addition to standard features, KENNEDY A.W.W.A. Valves have reduction gearing, gear cases, by-passes; indicators and rollers, tracks and scrapers available on 16" and larger sizes. Gearing is always furnished on 30" and larger valves.

KENNEDY VALVE MFG. CO.
ELMIRA, NEW YORK
VALVES
FIRE HYDRANTS

• WRITE TODAY FOR A.W.W.A. BULLETIN 561

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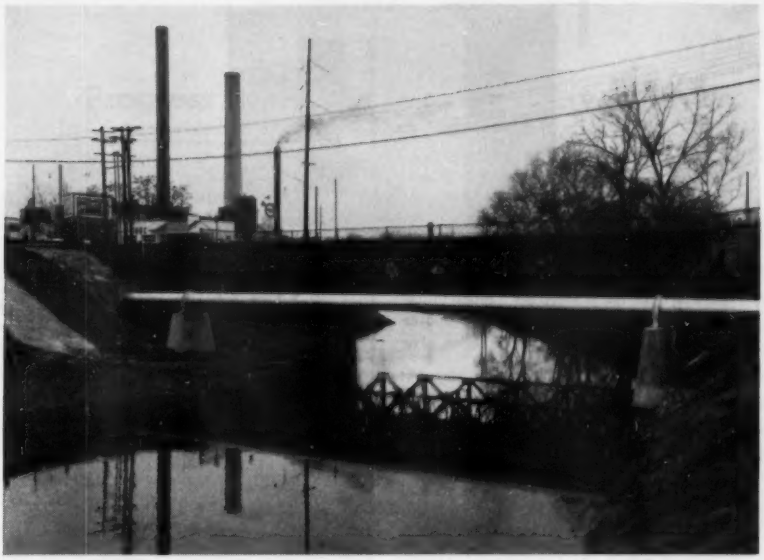
ARMCO STEEL WATER PIPE SPANS 92-FOOT STREAM

New steels are born at Armco



When Springfield, Ohio, had to take a 30-inch-diameter water line across a stream, Armco Steel Pipe provided an easy solution. Armco Pipe has ample beam strength to span the 92 feet from pier to pier.

This high beam strength also pays off in ordinary in-the-ground installations. With Armco Pipe, neither washouts nor ground settlements disrupt water service. The pipe has sufficient beam strength to span these bad spots.

You too will find that Armco Steel Pipe offers many advantages including cost savings and safer water lines. Write for a free copy of the folder, "Armco Steel Water Pipe Delivers All the Water You Pump." Armco Drainage & Metal Products, Inc., 6009 Curtis Street, Middletown, Ohio.

ARMCO DRAINAGE & METAL PRODUCTS

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
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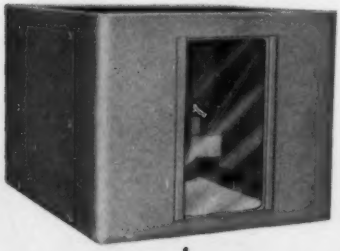
NOW "Add-To-Design" PAVES THE WAY TO SIMPLER FEEDER INSTALLATIONS



The W&T Series A-728 Dry Chemical Feeder forms a base for a complete feeder installation. Standard components are available —designed for use with the Feeder. For instance, the A-728 permits

. . . use of hoppers in standard lengths and sizes—ending your hoppering problems.

. . . choice of solution tanks—corrosion resistant and tight for the chemicals you use.

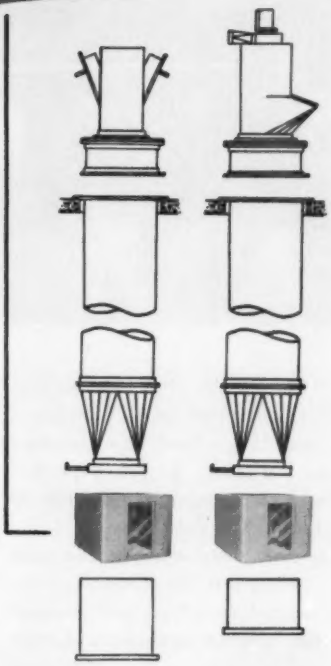
. . . direct feeder mounting of standard dust collectors, bag loaders, screens—eliminating extra structural supports.

. . . use of overhead supports—to eliminate your floor stress problems.

This means you use standard components to build your own custom installation without special design . . . saves you time and money.

■ ■ ■ ■

Write us for information to help you build your own feeder installation—easily and simply. Address Dept. MV-3.05



WALLACE & TIERNAN INCORPORATED

25 MAIN STREET. BELLEVILLE 9. NEW JERSEY

Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 51 • OCTOBER 1959 • NO. 10

Progress in Saline Water Conversion

Everett D. Howe

A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Everett D. Howe, Prof., Dept. of Eng., Univ. of California, Berkeley, Calif.

EXPERIMENTAL activity in the demineralization of water and in installation of new plants is going forward at an accelerating rate. Whereas 5 years ago the aggregate worldwide capacity of land-based distilling plants was about 5 mgd, the present capacity is more than 11 mgd and it is possible that 6–10 mgd will be added in the next 5 years. Likewise, the installed capacity of electrodialysis plants—less than 0.1 mgd 5 years ago—today is approaching 3 mgd, and has prospects of building up rapidly. Although much of this growth is due to drought and necessity, at least part of it stems from the increased effectiveness of available equipment made possible by the research and development activities of the past few years.

Research and development efforts in the United States have set price goals based on the present maximum costs for normal water supplies. Specifically, these are $125 per acre-foot for municipal or domestic uses and $40 per acre-foot for irrigation, or 38 cents and 12½ cents per thousand gallons respectively. Distillation and other commercial processes have not yet approached the higher of these figures closely enough to make them practical. Hence, most of the production plants are located outside the United States, in places where fresh water is either totally lacking or far more costly. The few plants in the United States are either connected with power plants where extremely pure water is needed, or where the price being paid for water is many times the figure quoted above.

The costs cited for water produced by multieffect distillation have been of the order of $3 per thousand gallons without concurrent electric power generation in the same plant, and $1.75 per thousand gallons with power generation. Research has therefore been in two general directions, one group of efforts being aimed toward the improvement of existing commercial processes and the other toward the development of processes not previously applied to the demineralizing of water.

Demineralizing Equipment

The demineralizing schemes which may be regarded as commercially feasible at this time are thermal distillation, vapor compression distillation, electrodialysis, and ion exchange. Distillation is being used primarily for desalting sea water, electrodialysis for demineralizing waters containing up to 4,000 ppm total dissolved solids, and ion exchange primarily for softening waters that contain calcium salts.

The newest large distilling plant placed in commission is a six-effect submerged-coil plant in Aruba, which can produce some 2.5 mgd of water together with 10,000 kw of electricity. This combination of water and power production is expected to reduce the fuel chargeable to the water plant sufficiently so that water can be sold for $1.75 per thousand gallons (this includes 80 cents fuel costs, 65 cents capital costs, and 30 cents maintenance and operation). Sonderman (*1*) reviewed these costs and concluded that the ultimate development of this type of equipment could be expected to yield water at about $1 per thousand gallons with concurrent generation and sale of electric power.

The problem of reducing costs is being given attention by a number of experimenters. Further reduction of fuel costs could be accomplished by increasing the gained-output ratio through the use of more effects than six. Badger and Standiford (*2*) proposed the use of twelve effects, which presumably would cut the fuel costs of the six-effect plants in two. As this requires more equipment, it might be assumed that the capital expenditures would thereby be doubled. The twelve-effect proposal also includes the use of ferrous rather than nonferrous materials in the heat exchangers, however, and the savings thus accomplished are expected to compensate for part of the increased cost of added effects. Whether or not this design can produce the desired results may be known soon, as this type of plant has been selected as the first of the five plants to be constructed under the Department of the Interior's $10,000,000 demonstration program. The demonstration plant will be designed for 1-mgd capacity and will be located on the Gulf Coast at Freeport, Tex.

Multiflash Evaporators

Another development of considerable current interest is that of the multiflash system, in which flash evaporation occurs during 25–40 stages of flashing due to small decrements of pressure. This scheme was described by Silver (*3*) and is being developed by several firms in the United States and Great Britain. At least three plants of 0.1-mgd capacity or more are under contract at the present time, one of these being the 0.1-mgd plant to be installed by the Southern California Edison Co. in connection with its Mandalay steam power station at Oxnard, Calif. This plant is to have some 26 stages of flash and will be used initially to explore the possible economies of various conditions of operation.

The merits of the multiflash system are cheaper construction and a higher average temperature difference in the heat exchangers than previous designs of multiflash distillers. The multiflash unit consists of two or three shells in each of which there are twelve or more stages. The heating (condenser) tubes are secured to the tube sheets at the ends of the shell and run continuously through all the stages within the shell. Stages are separated by diaphragms

perpendicular to the tubes and extending to the walls of the shell. The tubes pass through holes in the diaphragms, which fit closely to the tubes and are packed to prevent leakage of steam from stage to stage along the tubes. Because the pressure drop across each diaphragm is small, the construction may be fairly light. Costs and performance of this type of equipment are not yet well known but should be established soon, as the second Department of the Interior demonstration plant will probably be of this type and the three contract plants already mentioned should furnish data.

A third effort to increase economy of multieffect distillation is that of Leroy Bromley of the University of California's sea water conversion project. His design makes use of thin films produced by centrifugal forces to increase heat transfer rates to the point where 30 effects can be placed in the same temperature interval as is now being used for the six-effect units. A unit using 30 effects to produce an estimated 10,000 gpd is under construction and should be on test late this fall. It consists of 31 copper plates 4 ft in diameter and arranged along a vertical shaft at approximately ½-in. intervals. Warmed sea water is delivered to the upper side of all plates but the top one near the center shaft, and flows toward the periphery under centrifugal forces. Regulation of feed rates permits the maintenance of very thin films and thus allows evaporation at high rates from the film. Steam is brought into contact with the lower side of the bottom plate to furnish the heat input.

With this arrangement sea water evaporates from the top of each plate and the vapor is condensed on the bottom of the plate above. Mixing of the streams of outgoing brine and condensate is prevented by a narrow splitter ring placed around the periphery of each compartment midway between the evaporator plates. The pressure distribution across the stack of plates is produced by vacuum equipment. A countercurrent heat exchanger is built into the periphery of the rotor so that the outgoing condensate and brine streams are used to preheat the sea water feed. If successful, the heat demand for this scheme should be only one-fifth that needed for the six-effect plants previously described. Capital costs can be estimated with some accuracy only after the test unit has been run and evaluated.

Scale Control

After fuel costs and capital costs, the important costs are those of maintenance and operation, and in this regard the problem of scale control has an important effect. The deposition of scale, like any other crystallization or precipitation process, results from local supersaturation of a solution. Solutes with inverted solubility curves, such as calcium sulfate, may reach supersaturation through mere temperature changes and thus produce scales on surfaces where liquid heating is taking place. Other solutes, such as magnesium hydroxide and calcium carbonate, may reach supersaturation locally because of evaporation, heating, or the change of pH caused by gas evolution. The rate of scale deposition in evaporators is thus related to the rate of evaporation, the pH of the feedwater, the temperature, the average brine concentration, and the rate of brine circulation over the evaporating surface. Summaries of work done have been made by Neville-Jones (*4*), by Emmett (*5*), and by Badger and Banchero

(*6*). It is generally concluded that scale deposition can be prevented by such methods as contact stabilization, seed recycling, the use of additives, and forced circulation. The author was much impressed, during a recent visit to Kuwait, Arabia, with the considerable success in scale control achieved in a triple-effect distiller plant. After difficulty with scaling of the units caused by the very saline water in the Arabian Gulf (43,000 ppm salinity), a scale control scheme was devised which permits over 10,000 hr of scale free operation between shutdowns of the plant. The tube bundles are surrounded with a close-fitting metal jacket to reduce the brine retention time to a minimum and a recirculation pump is used to remove brine from the bottom of the tube bundle and return it to the top of the bundle as a spray. The feed to the system is treated by the addition of a small amount of sodium tripolyphosphate plus a dispersing agent. Operating temperatures of the brine are kept below about 180°F to avoid hydrolysis of the polyphosphates. At Curacao, Netherlands Antilles, and Aruba considerable success in scale control has been achieved through pH control with ferric chloride, which either is added as a chemical or is generated electrolytically by sacrificial iron electrodes in sea water. Costs of scale control methods vary from 2 cents per thousand gallons of product.

Sonderman (*1*) used the costs of the Aruba plant for estimating the costs of possible future large distiller plants of the same general type. He came to the conclusion that a reasonable ultimate goal would be $1 per thousand gallons. He assumed the fuel cost to be 6 cents per gallon for oil (equal to about 40 cents per 1,000,000 Btu). He also assumed a 10 per cent improvement in evaporating efficiency. If many more effects are used, as in the Badger or Bromley proposals, the fuel cost could presumably be reduced to 20–50 per cent of present costs. This would doubtless be accompanied by increased capital and maintenance costs, so that the net reduction in total cost could conceivably be of the order of 20–30 per cent.

It is fairly well agreed that thermal distillation can be depended on ultimately to produce water at costs of about $1 per thousand gallons, and at this price it will meet the needs of many consumers. Whether or not the price can be reduced substantially below that amount is problematical.

Vapor Compression

Vapor compression distillation plants produce about 200 lb of water per pound of fuel, whereas existing multi-effect plants produce a maximum of 70 lb. Individual vapor compression units produce only about one-tenth of the daily output of maximum-size multieffect units, however. A size limitation is imposed by the vapor compressor.

Research on the vapor compression plant has been directed primarily towards increasing the rate of heat transfer in the evaporator-condenser. Hickman (*7*) has developed a rotating heat transfer surface which is said to result in overall heat transfer factors four or five times those in stationary evaporator-condensers. More recently Lustenader and others (*8*) have described equipment using vertical tubes with which vapor condenses on the outside and water evaporates on the inside. Heat transfer coefficients are at least ten times those of conventional shell and tube evaporators. The special features of these tubes are the internal rotating wiper blades, which

maintain a thin film of water on the inside walls of the tubes, and the vertical flutes, or corrugations, on the outside. The latter have a small radius of curvature so that surface tension of the condensed drops of water causes the convex portions of the tube wall to remain dry and the concave portions to serve as channels for draining off the condensate. The dry portions of the tube insure dropwise condensation at high rates.

Another scheme for increasing the heat transfer rate is to increase the liquid velocity through the tubes by forced circulation. Experiments by Dodge and Eshaya (*9*) indicated that velocities of 7–8 fps would increase heat transfer coefficients and yet not require unduly large amounts of energy for pumping. Based on their experiments, Dodge and Eshaya have estimated production costs to be from 70 cents to $1 per thousand gallons for plants producing 10 mgd.

The most economical distillation combination seems to be a combination of a vapor compression distiller, with a steam plant and turbine for compressor drive, and a multieffect plant to use the steam discharged from the turbine. This combination has been proposed by several engineers, but, so far as the author is aware, no prototype installation has been made.

Freezing

The general principle of "cold distillation," or separation by freezing, is that, when sea water is subjected to sustained temperatures below 32°F but above its eutectic temperature, the water crystallizes as ice but all of the salts remain in solution. Presumably the ice crystals can then be separated from the brine and melted to produce liquid water. There would be an apparent advantage from the energy viewpoint in that the latent heat of fusion is only about one-seventh of the latent heat of evaporation. It has been found quite costly to separate the ice from the brine, however, and the lack of variation of the freezing point with pressure makes it difficult to use the heat regeneratively.

Recently a number of investigations have been made in this general field. Henrickson (*10*) investigated the costs of producing ice by using various machines available today. He concluded that this portion of the process alone would cost nine times the allowable amount for the entire cold distillation process. Because all the devices considered were indirect freezing units—that is, they used refrigerants which were separated from the ice-making compartments by metallic surfaces—he concluded that only direct freezing methods would be feasible. Zarchin's proposal (*11*) was one in which freezing would be direct and would be produced by flash evaporation of water in a vacuum chamber at a low temperature. The vapor produced would be compressed and the heated vapor would be used for melting ice previously formed. The inventor is said to be working on certain features of the equipment, but, so far as is known, he has not yet demonstrated the practicability of his process as a whole. The Carrier proposal (*12*) is similar in that it involves a direct flash freezing–evaporation process, but, in addition, a countercurrent washing process has been developed for stripping the brine from the ice. Experiments with the laboratory plant were so successful that a 16,000-gpd pilot plant is now being designed under a contract for the Department of the Interior.

Another variation of the direct-freezing process is the use of an immiscible refrigerant in direct contact

with the water to be frozen. Wiegandt (*13*) has experimented with isobutane as a refrigerant, and the use of other materials has been suggested by Zarchin (*11*) and by Rosenstein and Gorin (*14*). So far no complete equipment of this type has been put together, and the problems of design are therefore not completely known. Separation by direct freezing is closely related to vapor compression distillation, and differs in that the volume of water obtained from the cold distillation plant is much larger than that which passed through the compressor as vapor. As the energy required is dependent primarily on the quantity of vapor compressed, cold distillation could be more economical of energy than vapor compression if the ice and brine could be separated at negligible cost.

Vacuum Flash Distillation

The University of California's sea water conversion project has long been interested in the use of vacuum flash distillation (*15*) as a means of bypassing the use of fuel or other high-grade energy. The general scheme is to utilize any two sources of water that have different temperatures to provide heat for vaporization and power generation as well as a coolant for condensation. With temperature differences of about 30°F, the warm water is delivered to a vacuum chamber where a small portion (0.5–1.0 per cent) evaporates and the remainder is correspondingly cooled. The vapor is then passed through a turbine wheel on its way to the surface condenser, where the colder water supply is used to carry away the latent heat from the condensate. By a suitable division of the available temperature difference between evaporation, power generation, and condensation, it would be possible in large plants to generate enough power to operate all of the pumping and vacuum machinery. A complete plant of this type has been assembled at the University of California. It has been operated at rates up to 2,000 gpd. Carryover of liquid drops has been the limiting factor, and current experiments are directed toward its prevention.

Studies of this system have been made by Nizery (*16*) and Mulford (*17*), but no prototype plant exists. It is interesting, however, to note that the new multiflash plant to be installed at Oxnard will probably have the last few stages in a separate case so that vacuum flash distillation of the main condenser cooling water can be studied. No power-generating element is included. Although the scheme is limited in its application to a comparatively small number of locations, it could make a contribution to solution of water problems in those places.

Solar Distillation

Solar distillation is another means of using energy from nonfuel sources for water distillation. The simplest, and most widely investigated type of equipment for this purpose is the roof still, in which a sloping transparent cover is used to enclose a pool of water. Solar energy passes through the transparent cover and serves to warm the water, utilizing the "greenhouse" effect. Water then evaporates from the warm surface of the pool and is carried as humidity to the colder surface of the cover, where it condenses. Condensate is collected from the lower edge of the transparent cover.

Many variations of this idea are possible. The University of California has worked extensively (*18*) on units set on stilts about 3 ft above the ground, whereas the new Department

of the Interior installation in Florida consists of units set directly on the ground. Telkes (*19*) and the Bjorksten Laboratories (*20*) have worked on flat-type units in which the pool of water is replaced by a moist wick. This has the advantage that the collector surface (wick) can be made perpendicular to the sun's rays and the need for insulation of the bottom for protection from heat loss is eliminated. Workers in other countries have used materials such as asbestos-cement and vermiculite cement to overcome local problems.

Although much has been learned from the work done thus far, solar distillation has become semicommercial only in Algeria and Australia. In these countries solar stills are being used in family-size installations for the production of drinking water from saline ground waters. Construction costs and land requirements have been too great to make large installations attractive in the United States.

All forms of distillation suffer from the disadvantage that the energy requirement is nearly independent of the initial salinity of the water—that is, nearly the same amount of energy is required whether the feed to the plant is distilled water or sea water. This is because all of the product water has to undergo a phase change.

Electrodialysis

Electrodialysis is the removal of dissolved ions from water by the migration of the ions through membranes as carriers of electric current. The recent development of selective membranes—that is, with either plus or minus electrical charges—has made possible the placing of many membranes in series between electrodes and has increased the electrical efficiency very greatly as compared with the three-compartment (two-membrane) cell, which is the limit with nonselective membranes. Electrodialysis has the advantage that the energy required is proportional to the number of ions removed and, therefore, to the initial salinity of the water. The installations processing saline water with a total dissolved-solids concentration of less than one-seventh the concentration in sea water have required far less energy than distillation. Up to the present, however, the actual equipment demands more electrical energy for sea water feed than does the vapor compression machinery. The explanation generally given for this is that the electrical resistance of the membranes is too great. For this reason, most of the existing plants are intended for treatment of brackish water.

The largest electrodialysis plant—capacity 2.5 mgd—is located in the Orange Free State, Union of South Africa, and processes water of 3,000 ppm initial salinity. The individual units in this plant (presses) accommodate flow rates of 625,000 gpd. A smaller plant—28,000 gpd—has been installed recently in Coalinga, Calif., and is fed with well water containing more than 2,000 ppm total dissolved solids.

Development work on dialysis equipment has been in two general areas, membrane development and cell arrangement. Recently, membranes have been made which have good permselective properties, are mechanically strong, and have considerably less resistance than those previously available. Cell arrangement studies are directed toward a greater percentage utilization of the area of the membrane, as some designs utilize as little as 50–60 per cent of the area.

Problems which have arisen in the operation of this type of unit have been

dealt with by Hamaker (*21*), Cooke and others (*22*), and Powell and Guild (*23*). The most generally encountered problem is that of scaling. Alkaline scales are troublesome in the concentrating compartments when the diffusion of ions to the surface of the anion membrane in the diluting cell is insufficient to carry the current. Water is then electrolyzed and hydroxide ions pass through the membrane carrying the current and increase the pH in the cell. This increase is often enough to permit crystallization of materials such as magnesium hydroxide or calcium carbonate and limits the allowable current density. The condition may be offset by the feeding of acid or by the periodic reversal of the cells, both electrically and hydraulically.

Although the present costs of water produced by electrodialysis are several times the goal figures, the equipment must be regarded as in the early stages of development, and the costs of the process may be reducible by usage. It is probable that one of the demonstration plants of the Department of the Interior's program will utilize this process, and, if so, this should give a considerable impetus to its development.

Ion Exchange

Ion exchange is best known for its use in softening fresh water. The unwanted calcium and magnesium ions are replaced in the water by sodium ions, low concentrations of the latter being quite acceptable in the product water. Water that needs to be demineralized, however, generally has far more sodium and other ions than can be tolerated. A simple exchange with soluble metallic ions is of no value. Several other possibilities exist, however.

The life raft emergency water kits used during World War II contained silver zeolite. When crushed and immersed in an appropriate quantity of sea water, the silver ions would exchange with the sodium and other ions and thus go into solution. In the solution the silver ions would combine with the chloride ions and precipitate a filtrable solid silver chloride. The filtered water was then potable. Although this method was quite effective and was acceptable for wartime emergencies, the silver ions lost in the silver chloride were far too expensive. A second possibility lies in the use of acid and basic exchange materials which would exchange hydrogen and hydroxide ions for the unwanted ions in sea water. This, too, although satisfactory from the viewpoint of the product quality, is too expensive when the costs of acid and alkali for regeneration are reckoned.

The third possibility lies in the use of exchange ions that can be volatilized. Gilliland (*24*) suggested the use of ammonium bicarbonate. Stewart (*25*) has reported preliminary calculations and tests using ammonium carbonate as well as the bicarbonate. The basic idea is to exchange the unwanted ions with the volatile ions by charging the product water with the latter. This charged water is then heated and the volatile materials are collected and used for regeneration. With this combination, the gases produced by heating are ammonia and carbon dioxide. These gases can be redissolved, and the solution obtained can be used for regeneration.

As reported by Stewart (*25*), investigations at the University of California have disclosed the ion-exchange materials which are satisfactory for use with ammonium bicarbonate. Present efforts are in the study of means for degassing the water and concentrates with minimum quantities

of heat energy. Other possible exchange systems, such as those containing other volatile materials and those yielding salts with inverted solubility curves, are being considered.

Summary

Multieffect and multiflash distillation systems appear to be receiving the major share of attention at the present time. The first two demonstration plants of the Department of the Interior, as well as the majority of large production plants, are of this type. It is likely that the majority of installations for the next few years will be variations of thermal distillation. The limitation will be that of ultimate cost, estimated by conservative engineers to be about $1 per thousand gallons minimum. It is also likely that vapor compression, with about the same cost limitations, will find early application. Its advantage will probably be that minimum cost may be reached at lower capacities than those for thermal distillation.

Electrodialysis has reached the stage of development where it produces fresh water from brackish water more cheaply than distillation and where its degree of dependability warrants extensive application. If sufficient numbers of plants of this type are operated over the next few years, it is possible that applications to sea water may come about by evolution.

Ion-exchange processes in general have not received sufficient attention. It is possible that combinations of ion-exchange and thermal or electrical processes could prove more economical than distillation alone.

Reversed osmosis, solvent extraction, and some other less well developed phenomena will continue to receive attention but cannot be expected to yield attractive processes until at least 5–10 years after the development of workable equipment.

The drain on fossil fuel resources of any distillation scheme, if developed in large sizes, will be such as to increase efforts to use nuclear energy, solar energy, and waste heat. Studies of nuclear energy indicate that it costs about twice as much as heat from fossil fuels. Solar energy will probably be used for a large number of small installations in the near future. Larger installations will probably appear later as a result of experience with, and evolution of, the small ones. The use of waste heat for vacuum flash distillation is likely to find limited application soon.

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Discussion

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The saline water conversion program sponsored by the Office of Saline Water of the US Department of the Interior has now passed the planning and experimental stage and has reached fulfillment to the extent of the installation, in the immediate future, of at least five demonstration units. This development has become a reality through the congressional authorization of an expenditure of $10,000,000 for such units.

It is now well established that there are many processes by which sea water and other saline supplies can be converted to usable fresh water. There are several such installations now in practical operation in the United States and elsewhere in the world.

There is much misunderstanding on the issue of the probable cost of saline water conversion. Many believe that the cost cannot reach, or even approach, the low price now paid by communities for natural fresh water. The writer does not share this pessimistic viewpoint in the light of recent developments, especially in equipment design and process improvements.

A few years ago the cost of conversion of sea water by conventional distilling apparatus ranged from $5 to $7 for 1,000 gal. More recently, installations have produced water for as little as $1.75 for 1,000 gal. This latter cost is still excessive and must be reduced, but it has been reliably predicted that the cost of salt water conversion will soon be well under $1 for 1,000 gal, and even a lower figure may be attained, possibly half that amount. The predicted reduction in cost of conversion, either by distilling plants or other processes, has been brought about by improvement in the design of equipment and more efficient operating techniques. In the past, distilling plants were constructed, in large part, of costly alloy metals. It has now been demonstrated that such construction is not necessary and much less costly materials, such as steel, aluminum, and concrete, can be employed.

An important factor in the reduction of conversion costs is the possible use of byproduct heat energy. Large potential savings in operation will accrue through the use of byproduct heat energy, especially when distilling plants are integrated with power stations, or have other available sources of inexpensive heat.

One of the problems of conversion that has been, or soon will be, solved is the control of scale on the heating surfaces of evaporators, and the prevention of corrosion. Experimental work thus far conducted demonstrates that both of these problems are controllable. Their solution will result in considerable savings in operating costs.

Rapid advances are being made in the efficiency of the membranes used in electrodialysis systems for treating brackish water. Further, there is strong indication that the conversion of saline supplies by freezing processes will have a place in the overall solution of water shortage problems.

In summary, there is definite assurance that the conversion of saline water to produce fresh water at a reasonable cost is fast reaching fruition, and the writer is confident that this will be a factor in the solution of the water supply problems throughout the arid and semiarid regions of the world.

Parallel Operation of a Municipal Water Supply and an Electric Utility

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A paper presented on Jul. 16, 1959, at the Annual Conference, San Francisco, Calif., by Peter C. Karalekas, Chief Water Engr., Municipal Water Works, Springfield, Mass.

THIRTY years ago, the board of water commissioners of Springfield, Mass., and the Turners Falls Power and Electric Co. entered into an agreement to utilize the same source—the Cobble Mountain Reservoir—for the dual purpose of a public water supply and the generation of electric power. Precedents for such a procedure and standards for a contract which would safeguard the interests of both parties were difficult to find. It speaks well for the foresight of the devisers of the agreement that no questions have arisen as to the rights and duties of the two parties to the contract during a quarter-century of utilizing the same source. The point of view of the purchaser of powerhouse rights, Western Massachusetts Electric Co., has been presented in a published article by Antonio Ferreira (*1*). It is the purpose of this article to describe the parallel-operation project from the standpoint of Springfield's board of water commissioners, as they were responsible for obtaining legislation to raise the money and to build the structures.

Background

The formation of a Springfield board of water commissioners was authorized in legislation adopted in 1872, when water supplied from local ponds by the Springfield Aqueduct Co. proved so inadequate that the citizens decided a new source was needed. In June 1872, the lack of water prompted the commissioners to acquire promptly the works of the private company. The price, including purchase of the distribution system, was $250,010.53. Makeshift sources, including the Connecticut River, were utilized for the next few years. In the meantime, engineers were called in to report on new sources of supply. They considered Westfield Little River, about 14½ mi to the west of the Connecticut River, and tributaries of the Chicopee River, in the town of Ludlow, about 3 mi northeast of Springfield. The Ludlow supply would require pumping but it was so much closer to the city than Little River, that first cost proved to be the determining factor. From 1875 to 1909, the city was served from the Ludlow supply, which soon became notorious for its tastes and odors. In 1904, open, intermittent sand filters were installed and operated with some success, but, as explained by the designer, they were incapable of ridding the water of unpleasant tastes and odors during dry seasons. Several engineers and the Massachusetts Board of Health advised against continued use of the Ludlow source, even though it could

have provided an additional 5 mgd. In March 1905, the city council authorized its consulting engineer to report on the Little River sources of supply, and in November 1905, the mayor and board of water commissioners petitioned the Massachusetts General Court for authority to appropriate the waters of Westfield Little River. After much opposition from the town of Westfield, the bill was passed.

The consulting engineers and the chief water engineer proceeded with the design and construction of structures west of the effluent pipe of the filters. These included Borden Brook Reservoir, in the upper end of the Little River watershed, the present intake or diversion reservoir, about 7,000 ft upstream from the filter site, a 6,200-ft intake tunnel, a raw-water settling basin, and the first unit of slow sand filters. All of these units are still in use, although the intake tunnel was enlarged in 1932. This first part of the Little River development had a dependable yield of 8 mgd, plus the yield from an additional 40.5 sq mi of watershed.

All water taken from Borden Brook Reservoir flowed about 4½ mi in the stream bed to the intake reservoir formed in the stream bed by a curved overflow dam. There, part of the water, as needed, was diverted to the filters through the intake tunnel, the excess water going over the dam.

Filter Plant Site

Springfield is one of several American municipalities effectively utilizing the economy and facility of operation of slow sand filters. The chief demerit of slow sand filters is that they require 30–40 times as much land area as rapid filters. Springfield authorities, at the turn of the century, were sufficiently far-sighted to purchase an area of about 415 acres, of which 20 were relatively level. This area is located at an elevation that makes possible the use of gravity conduits from the new source of supply on the Little River watershed—Borden Brook Reservoir—and gravity conduits to the distribution system of the city of Springfield, located 11½ mi to the east. As all slow filters are perforce of the gravity type, the elevation of the filters was an important consideration in the determination of the sizes of all conduits and the head available for the production of electric power. The first six units of the filters were built in 1908. Four larger beds, added in 1924, brought the acreage to 6.25 and the peak capacity to about 34 mgd. Additions in 1952 brought the total acreage to 8.25, and the peak rated capacity for short intervals was increased to 60 mgd. The last installation is described in a previous paper (*2*).

The raw-water settling basin of the filter plant was constructed, in 1908, with flow line at an elevation of 491 ft, and the intake reservoir was built at the same time with full reservoir level at an elevation of 496 ft (Fig. 1). These elevations became important factors in the late 1920's because they fixed the lower elevation of the operating head for the hydroelectric power plant under consideration.

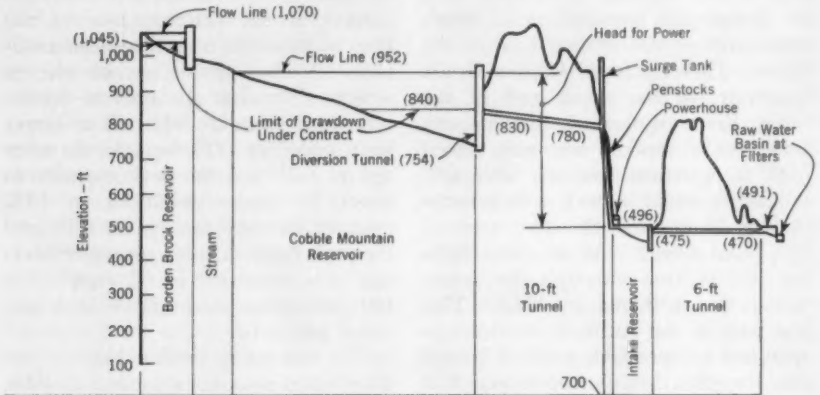
Hydroelectric Power Plant

As early as 1923, consideration was being given by the water commissioners to the future development of the Little River supply. The two alternatives were: [1] construction from time to time of a series of small reservoirs on the streams entering Westfield

Little River below Borden Brook Reservoir, and [2] at much greater immediate outlay of funds, construction of a single large reservoir with an unusually high, but short, dam. Consideration was also given to constructing Cobble Mountain Dam in stages. In his annual report for 1927, Chief Engineer Lochridge of the Springfield water utility reported:

All of these propositions were too expensive for the results obtained or too short-lived to appear economical when viewed from the standpoint of the ultimate necessary supply. With the continued growth of the city, . . . the construction of a full-height dam and a reservoir at Cobble Mountain is shown by all studies to be the only logical and complete development. . . .

As shown in Fig. 1, the full-height dam with 7-ft flashboards on the spillway would have a flow line at an elevation of 952 ft, or 456 ft above the full intake reservoir at elevation 496. As this high head must be expended before the city water reaches the existing raw-water settling basin of the slow sand filter plant, it was logical to consider a hydroelectric development. Such a development would provide much needed revenue to meet the burdensome financial charges for a $4,500,000 bond issue and to dissipate the high pressure head without the use of troublesome throttling valves.



Area – acres	213		1,134		8	
Distance – ft	3,000	2,200	14,000	7,300	2,000	6,200
Capacity – mil gal	2,500		22,829		55	
Yield – mgd	8		55 with Borden Brook	1,100		55+

Fig. 1. Profile From Borden Brook Reservoir to Basin at Filters

Data in parentheses represent elevations (in feet above mean sea level).

Legislation for Parallel Operations

Legislative permission for Springfield to generate and sell power is contained in Chapter 163, Special Laws of 1918. This act provides that the city, acting through its water commissioners, may utilize the fall of water on any part of its water system, now or in the future, to generate electricity. It also may sell power to any city, town, or corporation in the counties

of Hampden or Hampshire lawfully authorized to engage in the sale of electricity.

Under the authorization of Chapter 28, Laws of 1924, negotiations were started for the sale of power which could be generated under previously granted legislative permission. When definite proposals for power were received from the Turners Falls Power and Electric Co. (subsequently taken over by the Western Massachusetts Electric Co.), the funds needed to carry out the project could be more reliably estimated. Under Chapter 267, Laws of 1928, legislation provided for the borrowing of $4,500,000; the utilization of unspent balances in previously authorized funds; the retirement of bonds and payment of interest in 30 equal payments; the leasing to an electric company, for a period not exceeding 30 years, of the buildings, machinery, equipment, and appurtenances erected for the generation of power; the reserving to the city of the absolute prior right to use of the water; and the fixing of the assessed valuation of the power plant and appurtenances, which are located in three towns, at $1,100,000 for Granville, $1,000 for Russell, and $8,000 for Westfield.

As pointed out in the 1928 report of the water commissioners, the provisions of this act are most important. They open the way clearly and legally to the leasing of the entire power plant so that the city need not enter into business or take business risks for which it might not be equipped. The act permits the fixing of the amount to be paid for power at a figure which, received regularly without regard to the season or time of power production, will provide funds for the uniform retirement of bonds and interest. Provisions were made for the retirement of a small amount in bonds during the earlier years, and an increasing amount as the interest decreased, in such a manner that the annual interest and bond payments would be the same each year. This method not only arranged the payments so that the project could be financed without embarrassment, but it also permitted the use of the money received from the power plant to be applied directly to the payment of interest and retirement of the bonds without loss. The ready sale of the bonds would indicate that the plan of uneven annual retirements was not objectionable to the purchasers of the securities. The first bonds sold under this act were for $1,000,000 on Jan. 1, 1929. The provisions in the act for fixed valuations for the purpose of taxation followed conferences with the authorities of the three towns. These conferences resulted in agreements based on the cost of the structures. This static provision has served well to ward off any attempts at local revaluation for tax purposes at the expense of the city.

Contract for Parallel Operation

The construction of works that could be utilized both for public water supply and for power production by an electric utility was so novel in 1928 that few precedents existed on which to base the contract provisions. The contract entered into Jun. 21, 1928, by the city of Springfield and the Turners Falls Power and Electric Co. (superseded on Jan. 1, 1943 by the Western Massachusetts Electric Co., a subsidiary of the Western Massachusetts Companies) provides as follows:

The city of Springfield agrees:

1. To construct a storage reservoir on the Westfield Little River with its flow line at 945 ft [above] mean sea level, so

constructed that flashboards, 7 ft high, may be maintained thereon

2. To construct an outlet pressure tunnel about 7,260 ft in length from the storage reservoir to a point directly above the intake reservoir, the upstream elevation of the tunnel to be 830 and the downstream to be 780

3. To construct a concrete-lined tunnel and tunnel connections equivalent to a 10-ft–diameter circle

4. To complete this work by October 1, 1930

5. To pay for the power plant upon its completion the actual cost to the company or a sum not exceeding $1,100,000

6. To lease to the company for a period of 30 years from the day when Cobble Mountain Reservoir has filled with water to the level of 920 ft*; the right to occupy, use and operate the hydroelectric development, gates, and tunnel; the right to use excess water from the intake reservoir; the right to control part of the water in the Borden Brook Reservoir; and the right to build certain structures

7. To maintain all dams and reservoirs.

The public utility corporation agrees:

1. To build a hydroelectric plant to produce 23,000 kw of electrical power when operated at a head of 330 ft

2. To build trash racks, line the lower portion of the tunnel with steel, build a powerhouse, water wheels, generators, exciters, switches, switchboard, electrical circuits, and other necessary apparatus and equipment to deliver the generated energy

3. To build a roadway to the powerhouse

4. To build two 66,000-v transmission circuits on city property

TABLE 1

Record of Revenues, Charges, and Taxes for Cobble Mountain Development, 1929–58

Year	Amount—$			Year	Amount—$		
	Revenues From Power Lease	Charges† on 1929–30 Bonds‡	Local Taxes On Power Plant		Revenues From Power Lease	Charges† on 1929–30 Bonds‡	Local Taxes On Power Plant
1929		20,000		1944	270,600	259,035	26,714
1930		137,140		1945	271,500	258,550	27,814
1931		259,568	17,878	1946	271,450	257,868	33,347
1932	14,250	259,253	21,244	1947	271,450	257,968	35,559
1933	270,000	257,818	25,592	1948	271,475	257,825	35,605
1934	270,000	258,201	26,793#	1949	271,500	258,445	37,824
1935	292,500*	258,594	26,740#	1950	271,500	257,785	38,940
1936	270,000	259,740§	27,886#	1951	273,190	257,888	43,292
1937	270,600	258,710	29,518#	1952	273,135	257,710	43,298
1938	270,600	257,560	30,068#	1953	273,135	258,253	43,406
1939	270,600	257,270	28,984	1954	273,245	257,458	42,300
1940	270,600	257,820	26,759	1955	273,300	258.386	43,304
1941	270,600	257,173	29,585	1956	253,190	256,975	48,864
1942	270,600	258,345	26,725	1957	255,225	257,285	49,973
1943	270,600	258,280	26,704	1958	255,700	256,215‖	57,694
				Totals	7,040,545	7,383,112	953,309#

* Includes December 1934—that is, 13 months owing to shift in fiscal year.
† Interest plus amortization.
‡ A total of $4,500,000 was issued in bonds during 1928–30.
§ Maximum.
‖ Minimum after 1931.
$942,823.60 paid to Granville on $1,100,000 assessed value; $1,594.20 paid to Russell on $1,000 assessed value; $8,892.00 paid to Westfield on $8,000 assessed value.

* The date became Nov. 12, 1932.

5. To maintain and repair all plant under lease, and to surrender the leased plant to the city at the termination of the lease in good order and working condition

6. To aid in the measurement of the water and to conduct its operations so as to preserve the purity of the water.

Other provisions in the contract were that:

1. Allowance for slight adjustments in revenue be made by special draft requirements for variations in the quality of water and for special use

2. Whenever the electric company fails to provide sufficient water, the water be drawn from the outlet gate (Diversion Gatehouse) leading from Cobble Mountain Reservoir

3. A schedule be made of elevations in the Cobble Mountain Reservoir to which the reservoir can be drawn for each month of the year

The elevations at which Cobble Mountain and the Intake Reservoirs are controlled by flashboards and the openings permissible for taking excess water from the Intake Reservoir were also specified.

The contract stated that when city use averages 30 mgd, the reduction in revenue is to be $20,000, with further reductions as the city usage grows. A rental of $270,000 per year is to be paid in monthly installments.

An elevation of 1,045 ft is to be the limit of drawdown on Borden Brook Reservoir for power; this leaves in storage 1 bil gal of the total capacity of 2.5 bil gal. The water level in Cobble Mountain Reservoir is, according to the contract, to be so regulated and controlled that the city can at all times draw from the Intake Reservoir the amount required for supplying Springfield and any towns in which the city is or might become authorized to sell water.

It will be observed that, because the domestic water demand is growing constantly, the contract provides the city with a continuously increasing reserve at the reservoir. The elevations to which the reservoir can be drawn to provide for power are gradually to be raised, and the quantity of storage allowed the company is gradually to be decreased. Each 5-mgd increase in yearly city use also results in a decrease in the revenue from the powerhouse.

Yearly Payments

The contract provides for a basic payment of $270,000 and is subject to adjustment with increasing rates of diversion of water for municipal use. When the average daily draft by the city from the Intake Reservoir exceeds 30 mgd, $20,000 is to be deducted from the payment due the city. The reason for this deduction is that the power company has less storage for its optional use. When the average daily draft by the city exceeds 35 mgd, an additional $20,000 per year is to be deducted.

When the average daily draft by the city exceeds 40 mgd, an additional $35,000 per year is to be deducted.

Reductions in annual rent are to take effect in the year following the year in which the city's draft from the Intake Reservoir exceeds the indicated quantities.

Adjustment is also provided for peak rates of draft by the city from the Intake Reservoir whenever the city orders the power company to release and discharge water in such quantities that the Intake Reservoir is maintained at an elevation of 494 ft or higher (full reservoir elevation is 496 ft) for at least 20 hr each day; if the company is required to do this for more than 60 days in any one year, a

reduction in rental is allotted, and, if the number of such days is fewer than 60 per annum, an increase in rental is provided for.

Adjustments in rental are made by calendar years. Rental adjustments are calculated as daily charges for the number of days occurring as described above in each year in excess of or less than 60 days. For the first 3 years of contract term (until Nov. 12, 1935) no adjustment was made in daily charges. Thereafter, the adjustment rate was $10 per day up to and including the first year in which water was drawn by the city from the Intake Reservoir at rates exceeding 20 mgd. Thereafter the adjustments are $25 per day up to and including the first year draft exceeds an average of 25 mgd; $55 per day until the year after the year in which the draft reaches an average of 30 mgd; $95 per day until the year after the year in which the draft reaches an average of 35 mgd; and $130 per day until the end of the contract term, Nov. 12, 1962.

TABLE 2

Estimates of Revenues, Charges, and Taxes for Cobble Mountain Reservoir, 1959–62

Year	Amount—$		
	Revenues From Power Lease	Charges on Bonds	Local Taxes On Power Plant
Totals	7,040,545	7,383,112	953,309
1959	250,000	256,805	60,000
1960	250,000	141,158*	60,000
1961	250,000		60,000
1962	218,000†		60,000
Totals	$8,008,545	$7,781,075	$1,193,309

* 30-year $4,500,000 bond issue charges paid up Dec 1, 1960.
† Revenue from present contract ceases Nov. 12, 1962.

Revenue From Power

The revenues received each year during 1932–58 and calculated in accordance with the provisions outlined in the preceding paragraph are shown in Table 1.

It will be observed in Table 1 that the initial reduction of $20,000 per year for average flows in excess of 30 mgd was never made until 1956; the first reduction of $20,000 was proper then, because the city extracted water from the Intake Reservoir in 1955 at an average rate of 31.46 mgd. Payments of more than $270,000 for the years 1945–55 reflect the increase in rental earned by the city for not requiring high water levels in the Intake Reservoir.

The city has never to date had to pay a penalty for maintaining the level in the Intake Reservoir at 494 ft for more than 60 days in any one year. The water level in Cobble Mountain Reservoir has been so controlled that it has never dropped below the prescribed level of 820 ft. Table 2 shows the forecast revenues from power, from Nov. 14, 1958 to the termination of the 30-year contract on Nov. 14, 1962. The total is estimated at $8,008,545.

Charges

In Table 1 are shown the payments for bond retirement and interest during 1932–58. It will be observed that after 1931 they vary from $259,740 in 1936 to $256,215 in 1958. These are not equal payments, as might be expected with bonds of different face values.

In Table 2, the financial charges to the termination of the power contract on Nov. 12, 1962, are estimated and give a total of $7,781,074.50, which is $227,471.50 less than the revenues of $8,008,545. This bears out the

claim that the project would be self-supporting.

Overall Economy

It still remains to consider the local taxes to the towns of Granville, Russell, and Westfield, as provided in the 1924 laws. As shown in Table 1, these taxes totaled $953,309.40 to the end of 1958. In Table 2, taxes are forecast until Nov. 12, 1962; the total is $1,193,309.40.

TABLE 3

Overflows of Cobble Mountain Spillway Due to Storms, 1937–55*

Date	Overflow Elevation ft	
May 15, 1937	952.8	
Jun. 14, 1938	952.1	
Jul. 25, 1938	952.2	
Jul. 30, 1938	952.1	single storm
Jul. 31, 1938	952.3	
Aug. 1, 1938	952.3	
Aug. 7, 1938	952.3	
Aug. 8, 1938	952.2	
Sep. 22, 1938	953.4	
Jun. 1, 1939	952.2	
Jun. 2, 1939	952.5	single storm
Jun. 3, 1939	952.2	
Jun. 8, 1942	952.1	
Jun. 14, 1948	952.1	
Jun. 29, 1948	952.1	
Jun. 2, 1952	953.5	single storm
Jun. 3, 1952	952.7	
May 11, 1953	952.3	
Aug. 19, 1955	961.9	
Aug. 20, 1955	955.1	single storm
Aug. 21, 1955	953.2	
Oct. 16, 1955	955.4	
Oct. 17, 1955	954.1	single storm
Oct. 18, 1955	952.7	

* Spillway elevation 952 ft.

If these taxes are considered part of the charges against the hydroelectric project, there is a deficit of about $966,000 over 30 years. But this is seen to be most reasonable. In 30 years, the city has probably taken an average of 25 mgd from Westfield Little River sources. Assuming 4 mgd came from Borden Brook Reservoir which was financed by bond issues not relevant here, in 30 years at 21 mgd the city would have derived 229,000 mil gal from Cobble Mountain at a cost of $966,000, or about $4 per million gallons—an absurdly low cost.

If the Cobble Mountain development had been built piecemeal with no power development, as the water demands increased from 1932 to 1958, it would have cost more than $7,000,000, and the financial charges might have totaled $12,500,000. That would represent a cost for 229,000 mil gal or nearly $55 per million gallons.

These rough figures indicate the outstanding economy of the project as conceived and built, allowing for taxes of $1,193,000 on the power development.

Loss Over Spillway

As water passing over the spillway into the stream is of no use for power development, consistent efforts have been made to keep the reservoir as full as possible and still reserve some volume to absorb storms which might cause loss of water over the spillway. In Table 3 are recorded the fifteen storms in 26 years which have resulted in rises in the water level to above an elevation of 952 ft, which is that of the top of the permanent 7-ft additional spillway dam installed in 1938. It will be observed that only four storms resulted in a 12-in. crest on the spillway; of these, Hurricane Diane on Aug. 18–19, 1955 (rainfall at Cobble Mountain was 17.73 in. in 2 days) raised the water level to 960 ft, or 8 ft over the spillway. Landslides at that time caused the power station to be flooded, and access roads were damaged; it cost the power company about $50,000 and 4 weeks' loss of power. It was necessary to supply the needs of the city from the so-called

Diversion Gatehouse, the second outlet structure of the reservoir.

Operating Experience

All water for the city supply passes through the turbines at the powerhouse. When all three turbines are operating at a 420-ft effective head to produce 33,000 kw, they discharge at the rate of 1,100 cfs, or about 710 mgd. When operating at a 330-ft head to produce the normal output of 23,000 kw, they discharge a little less, probably 1,020 cfs, or 650 mgd. If the station were operated full time, there would be a tremendous draw on the storage, and the reservoir would be drawn down completely in 30 days. Because the power station can be put in service to develop full output in 1½ min, it is operated primarily as a reserve, for 40–44 daylight hours per week, never on Sundays or at night except for emergencies, and seldom more than 8 hr per day. The city is fortunate to have a storage volume in the raw-water settling basin at the filters of 40 mil gal at an elevation high enough above the filters to feed them adequately when drawn down to an elevation of 480 ft, although this necessitates bypassing the filter control level aerator. The rates of flow required for full operation of the three turbines set up velocities in the Cobble Mountain tunnel of over 14 cfs. In the last 27 years, however, there has been no evidence of erosion in this horseshoe-shaped, concrete-lined tunnel. When this high rate of flow reaches the Intake Reservoir, as much as 100 mgd can be diverted into the intake tunnel and thence into the raw-water settling basin, which has to be partially emptied to create hydraulic conditions for the high rate of discharge. Even when there is a discharge of 100 mgd from the Intake Reservoir through the intake tunnel, there is a leftover flow of 550 mgd. This must be passed over the overflow dam of the Intake Reservoir, as the reservoir, even when cleaned of heavy sediment, holds only 41 mil gal.

Fortunately, the combination of adverse conditions assumed in the design has not materialized during the past 26 years. For instance, it has never been necessary to lower the water level in Cobble Mountain Reservoir as provided for in the contract. The cooperating interests have manipulated the outlet gates in such a manner as to keep the big reservoir as full as possible. At the same time, storage is provided if sudden rains cause the waste of water over the spillway, as discussed previously Owing to the large quantity of storage in the raw-water settling basin, the city can fill there and then close the inlet valves. This allows the power company part of a day to lower the water in the Intake Reservoir 16 ft below the crest of the overflow dam and gives the company 16 ft of additional storage without wasting city supply.

By the terms of the present contract, the powerhouse and its equipment and transmission system on city property, all restored to good condition, will be turned over to the city in 1962. The city will then be in a position to execute a new contract for power generation. This should assure the city of a yearly income for financing future improvements.

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Requirements of a Model Water Law

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A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Arthur M. Piper, Div. Hydrologist, USGS, Menlo Park, Calif.

STATUTORY law and common law together seek to define both the acceptable extent of personal privilege and the limitations that must be placed on such privilege in an orderly society. In the field of water rights they are concerned with the definition of privilege and limitations in water use according to experience in various environments. Inevitably both forms of law involve compromise, and inevitably they lag behind experience; under the principle of legal precedent, the privileges and limitations they seek to define become absolute and rigid. Therein lie the causes of serious legal difficulties, particularly in a society and economy that are expanding so explosively as those of the United States.

Each of the doctrines and principles of water law—riparian, reasonable use, correlative rights, prescriptive rights, prior appropriation, and police power license—was suited for the economic and hydrologic environment from which it evolved (*1*). With the possible exception of police power license each has inherent rigidities that can become fallacious as the environment changes. Over most of the United States, economic aspects of environment have changed, and are changing, drastically from those that engendered water laws. Each of the current doctrines of water law can fail when there no longer is enough space to run from an area with complex water problems to an area with simpler ones or, hopefully, none. In certain parts of the United States, space to run no longer exists.

The physical laws of the natural occurrence of water are absolute and timeless limitations. Unfortunately, man's knowledge of these natural limitations is incomplete and has only recently begun to approach what is needed to resolve current water supply troubles. Hydrologic knowledge has come long after the establishment of the sometimes contradictory rigidities of common and statutory water law. Contradictions between outmoded, but rigid, policies and the knowledge gained through improved hydrologic methods are just one more source of potential difficulty.

In this situation, what are the shortcomings of current water law? What philosophy of water law appears most advantageous in the face of known and prospective conditions in the United States? Is a uniform model law possible in view of the diversity of conditions?

Law and Hydrology

Existing law differentiates water into classes, as though each class were distinct in kind and for all time. The legal class distinctions are commonly contradictory to hydrologic fact—as, for example, with "diffuse" surface waters

and "percolating" ground waters. A very large part of the usable surface water supply was, at some time between its precipitation as rain or snow and its collection in watercourses, "diffuse," in the legal sense. Applicable law permits—sometimes forces—the disspiation of this water before it can collect into the resource that is becoming more and more vital to the expanding population and economy. In the legal sense, only certain ground waters are "percolating"; these are deemed in many states to be not susceptible of control. In the hydrologic sense, however, nearly all ground waters percolate. They must, therefore, be covered by water laws if such laws are to be effective tools for water management. Such fine distinctions in terminology and concepts would be of little moment in a well watered, sparsely populated area, but in areas of sparse water supply or dense population they can become tremendously significant. Any adequate water law must derive from a common ground of agreement between legal and hydrologic concepts.

Surface and Ground Water

Hydrologically, most ground water bodies are functional components of the natural system of land drainage. They are replenished continually from the same source that generates surface streams—rain and snow. Ground water is conveyed, slowly, to streams and commonly is a principal source of dry-season runoff. A model water law must take this interrelation into account and cover both surface waters and ground waters under a single legal principle.

Unfortunately, in contrast to this implied model, states that have enacted comprehensive ground water codes have usually done so years or decades after the enactment of their surface water codes. The two codes have been coordinated only loosely, if at all Surface and ground water rights are commonly recorded and administered separately. In this situation, the rights of individuals in interconnected supplies of surface and ground water have often become confused. Such confusion is aggravated in states that apply different principles of law to surface waters and ground waters. For example, surface waters may be considered subject to public appropriation, whereas ground waters may be considered appurtenant to the overlying land and therefore subject to private ownership. As pointed out by Hutchins (*2*):

> Correlation of rights is not feasible in a state which, for example, recognizes exclusive appropriation rights in surface streams and rights of absolute ownership of percolating waters. Even if such percolating waters are conclusively proved to be physically tributary to a surface stream, the stream appropriator obviously can have no legal claim on them if they are held to be the absolute property of the overlying owner.

Riparian Doctrine

The essence of the riparian doctrine is that the right to use water is a property attached to and inherent in land that abuts on a stream or overlies a ground water body. In effect, the usable water supply of a particular area is owned by certain preferred landowners; nonriparian owners must purchase a water source.

There is an obvious hydrologic fallacy in this doctrine—that is, exclusive and unlimited right to use water attached to specific parcels of land can be real only if the water does not move laterally. In streams the water moves in an obvious way—from the jurisdiction of one riparian owner to that of

another. Beneath the land surface, most ground water moves just as definitely, though slowly. The fallacy was not of serious consequence in the environment from which the riparian doctrine sprang, where there was a humid climate coupled with a simple agricultural economy and a sparse population. Under those conditions the overall surplus in precipitation ordinarily insured that the limited water supply requirements were met in full.

Under the riparian doctrine, the theoretical right of unlimited water use may become a figment in urban or metropolitan areas, with intensive agricultural development through irrigation (which is expanding steadily even in the humid East) or with an intensive industrial economy. Even in a humid environment, large demands for water at the places of concentrated use may become mutually exclusive or may drastically curtail the supply available to riparian users downstream. In view of the nation's explosive growth in population and in industry, the riparian doctrine may become untenable even in the best watered areas.

Surface Water Appropriation

When it applies exclusively, the appropriation doctrine affords an obvious and practical mechanism for curtailing the use of water from streams or lakes whenever such use exceeds the total supply. Adequate records of the valid appropriations and of streamflow are necessary, of course, but such records usually are available or can be developed. On at least two counts, however, the appropriation doctrine may greatly complicate the means to effective management of surface waters. First, "grandfather" rights commonly foster overly generous and inefficient use of water in certain parts of a basin, even while junior appropriators are forced into excessively competitive use. Second, in most basins in arid regions, junior appropriators hold valid claims to use of water that is available only in the wettest years.

It is argued, with some practicality, that the economics of water use will resolve such difficulties in due course —that when the need is sufficient, the obstacles will be liquidated through purchase. Outright purchase seems a needless burden on water supply management, however, when the real obstacle might be resolved by reasonable restrictions to achieve uniform efficiency in water use within a given basin. A model water law must take these realities into consideration.

Ground Water Appropriation

Exclusive application of the appropriation doctrine to ground water may seem to offer the same mechanism for coordinating use with supply; in actuality, however, the mechanism is far from effective for several reasons:

1. When the natural regimen of a ground water body is changed by withdrawal or some other act of man, the effects are often obscure and slow to develop.

2. Extensive hydrologic records and investigations are prerequisite to monitoring the behavior of a ground water body under use. Records and results of such investigations are available for only a few areas and for no complete state. Consequently, overdraft usually escapes recognition while it is small.

3. Under most existing ground water codes, incipient or actual overdraft would invoke a declaration of a restricted-use or critical area and the prohibition or restriction of additional wells or increased withdrawals. Such prohibition or restriction might

be futile; development could be checked, but not necessarily its adverse effects.

4. The causes and effects of ground water overdraft are not immediately or fully reversible. Consequently, cutting off withdrawals in the reverse order of their priorities of appropriation does not insure that the march of overdraft will be reversed. Under the circumstances stated all too briefly here, responsible officials are often reluctant to invoke statutory provisions, under the appropriation doctrine, for reducing use of ground water. They may have either of two reasonable doubts: [1] that the available facts would suffice to sustain the administrator in any appeal from his order for reduction, or [2] that the statutory procedure would in fact restore the status of the earlier appropriators.

Weakness of Appropriation

New Mexico has had the longest experience under statutes applying the appropriation doctrine to both surface water and ground water. Four examples from that experience are enlightening (*3*):

1. Under native conditions, certain large springs in the northern part of the Roswell basin acted as natural relief valves to a large body of artesian water. The flow from these springs was quickly appropriated by early settlers. Owing to subsequent intensive development of wells, the artesian head so decreased that the flow from individual spring orifices either ceased or diminished greatly. Thus, certain holders of the earliest surface water rights in the basin abandoned their developments.

The artesian basin, having been developed excessively, was closed to further appropriation by the state engineer. Under this action, however, holders of the depreciated surface water rights were precluded from obtaining relief by tapping the ground water body that had sustained those rights under natural conditions. Applicable law treated surface water and ground water as though they afforded distinct and separable sources of supply, whereas, in fact, no such separation existed.

2. The Pecos River Compact, which governs the allocation of stream waters between New Mexico and Texas, provides:

> New Mexico shall not deplete by man's activities the flow of the Pecos River at the New Mexico–Texas state line below an amount which will give to Texas a quantity of water equivalent to that available to Texas under the 1947 condition. . . . In maintaining the flows at the New Mexico–Texas state line required by this Compact, New Mexico shall in all instances apply the principle of prior appropriation within New Mexico.

These terms pose a prospective dilemma. A considerable part of the base flow in the Pecos River was derived, under native conditions, from the artesian and unconfined ground water bodies of the Roswell Basin. Ground water developments have greatly diminished this base flow, however, although their ultimate effect on the flow of the river will not be evident for many years to come. The ultimate effect may be so great that the flow at the state line will be diminished to less than what it was in 1947. In this situation, suspension of the junior surface water appropriations probably would be ineffective, because in large part they do not involve base flow. Suspending the junior rights to ground water sources would, in theory, affect the river flow and ultimately might satisfy the terms of the compact. This remedy, however,

would take effect only over a long time and would not offer an immediate solution.

3. In an irrigated area, ground water development tends to concentrate around the most productive wells and the most productive lands. Consequently, some parts of a particular ground water source may become too heavily appropriated, whereas parts with less desirable lands or smaller yields of water remain virtually untouched. In the northern part of the Mimbres Valley, N.M., for example, the ground water supply has been fully appropriated in the vicinity of Deming. In the southern part of that basin, however, considerable additional draft might be dispersed over an extensive area with little detriment to prior appropriators to the north. At one time the state engineer permitted no further appropriations in certain areas of the basin, the boundaries of those areas having been fixed somewhat arbitrarily, of necessity. This approach proved unsatisfactory, especially near the boundaries of the designated areas. In consequence, the entire basin was closed to further development. As of 1951, the state engineer has not developed an acceptable formula under which continued appropriations might be permitted in areas of light development, even though they were denied in adjacent areas of optimum development.

4. One section of the New Mexico statute provides that the state engineer is to determine where public waters are available for appropriation. It was under this section that authority had been assumed for closing a basin either in part or in whole. A basic question has been raised by litigants, however—that is, does the state engineer have authority to make such determinations for whole basins or parts of basins, or must each application for a new appropriation be assessed on the merit of its individual situation? These are further problems to be covered by a model water law.

Police Power License

Where administrative control of waters is based wholly on the police power, a right of use commonly is in the form of a term license, with or without an effective option of successive renewals. Assuming that the policing agency is both omniscient and without bias, the police power doctrine might be acceptable in the nation's best watered areas, where the available supply may be ample for nearly all conceivable uses. An applicant would have reasonable assurance that a license or renewal would be issued and that its restrictions, if any, would not be onerous. At the other extreme, in poorly watered areas, no such assurance could exist; uncertain tenure in a right to the limited water supply might well preclude vigorous and stable economic development.

Certain proposed water codes would combine, in a single agency, police power to license and authority or responsibility to develop water resources on the part of the state. In the author's judgment, such a dual role would inevitably expose the agency to charges of bias, possibly to the extent of compromising its integrity and effectiveness. These are possibilities that a model law cannot ignore.

Conclusions

Water supply facilities are becoming progressively more costly and more complex; concomitantly, those who develop the facilities want assurance that their investments can be recovered within the life of the developments.

More and more, the rational solution for water supply stringencies will require concerted action by fairly large groups of water users who are willing to make mutual concessions to the common advantage. As the stringencies become more numerous and widespread, the interests to be compromised will become more diverse, and the nature of the desirable compromise may change substantially from time to time and from place to place. The author believes that the following concepts are emerging in the areas of greatest demands on water supplies:

1. An individual's claim to exclusive jurisdiction over any particular amount of water, to be used as he sees fit and then discarded, will fall to the pressures of common opinion.

2. One principle of the appropriation doctrine—that ownership of all water supplies rests in the public, collectively—will become dominant. Other principles of the doctrine will be modified in general opinion; appropriations of water will become contingent on a use which returns the greatest potential advantage to the public at that particular time and place; and the rule of "first in time, first in right" will be modified to discontinue the granting of absolute priority without regard to the manner of water use. In other words, the appropriation doctrine will become coupled to the police power of the state, in order to produce the optimum advantage to the general public welfare. A first step in this direction has been taken in the ground water code adopted by Oregon in 1955.

3. Water sources and reservoir sites on the land surface and water sources and natural reservoirs beneath the land surface will come to be managed as a single supply for allocation among all needs. To accomplish such control only an agency of the utility or improvement district type, either an arm of government or functioning under governmental license and regulation, would appear to have the necessary broad competence.

Thus, the three basic requirements of a model water law are: [1] that it afford the flexibility necessary for the nation as a whole effectively to manage its future water supplies, under reasonable but adequate checks and balances; [2] that, in defining rights of individuals, it prescribe only essential and minimum restrictions; and [3] that it afford to groups of water users all reasonable freedom to act concertedly, each conceding some part of its individual rights to the common advantage.

In the author's opinion, these requirements can be met by a proper application of selected aspects of the appropriation doctrine, the police power, and the improvement district philosophy. These must be coupled with wide education in the facts of hydrology.

It is doubtful that any single statute would be equally advantageous in all the diverse water supply environments of the United States. A realistic model might have a uniform basic theme with alternatives to suit particular environments. Drafting such a model is a far from simple task.

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New Aqueduct for the East Bay Municipal Utility District

James W. Trahern

A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by James W. Trahern, Mgr., Design Eng. Div., East Bay Municipal Utility Dist., Oakland, Calif.

THE East Bay Municipal Utility District of Oakland, Calif., is the second largest domestic water utility west of the Mississippi River in number of consumers. It is the sole distributor to a 228 sq mi area contiguous to the eastern shore of San Francisco Bay. The population of the service area is approximately 1,000,000. The average consumption within the area was 145 mgd for the past year.

The service area is developing rapidly, and the district's water use has increased greatly. It is now nearly three times as large as it was in 1940. Rapid development of the area is expected to continue for many years, and a rapid increase in water use will accompany the development. To meet the anticipated increase, the District is now engaged in making a firm plan for the construction of additional facilities for storage, transmission, and distribution, together with related facilities for pumping, filtration, and power generation. Arrangements have been completed for financing the plan to the extent of $283,000,000. All of the work connected with the plan is scheduled to be committed for construction in several stages during the coming 8 years. The Third Mokelumne Aqueduct, which is the subject of this article, is one of the features of the construction program.

Description of Aqueduct

The new aqueduct will be an 87-in. ID pipeline 81 mi long. Its capacity will be 100 mgd gravity flow and, with pumping, ultimately will become 170 mgd. It will be subjected to hydrostatic heads ranging up to 520 ft. If it should be constructed of steel pipe, approximately 110,000 tons of steel will be used. The cost of the completed line will be about $60,000,000.

The aqueduct will extend from the district's main source of supply at Pardee Reservoir in the foothills of the Sierra Nevada, across the San Joaquin River Valley, and will terminate at Walnut Creek within the district's service area. It will parallel two existing aqueducts and will supplement them. With the addition of this new line and its pumping facilities, the capacity of the aqueduct system will increase from 180 to 350 mgd.

The new aqueduct will be constructed in trench for a distance of 69 mi and will have a nominal earth cover of 4 ft. It will be supported aboveground on pile foundations and steel bents for a distance of 11 mi. It will cross three large rivers. It will be equipped with vacuum valves calculated to prevent its collapse in the event of rupture of the line, and to expel air to permit filling at the rate

of 30 mgd. It will be equipped with two automatic wasteways, strategically located. In the event of a major rupture of the aqueduct, these wasteways, activated by a change in hydrostatic pressure, will divert water from the line to locations where the discharge will do no damage.

Service Resources

In connection with the planning of a major construction project, an examination of resources available to supply and service the project can be useful. Proper consideration of such resources may well point the way to a sound design that will permit various manufacturers and contractors to bid under favorable competitive conditions. Fortunately, substantial resources are available to serve the district's aqueduct project.

Three major steel producers normally serve the local area where the aqueduct will be constructed. Each of two of them is able and anxious to furnish all the steel required.

Three manufacturers of steel pipe and two manufacturers of concrete pipe, all large companies with a great deal of experience in their fields, will compete for the job of supplying the pipe. Any one of these manufacturers could supply all the pipe needed within a reasonable period of time.

A large number of general contractors, well fortified with necessary equipment and experience, are interested and available to install the pipe. There is no concern over the matter of securing competitive bidding for this part of the work from well qualified firms.

For constructing the pile foundations to support the 11 mi of elevated pipeline, several well qualified local firms will undoubtedly submit competitive proposals.

There will be no problem in securing miscellaneous materials and equipment, such as concreting materials, air and vacuum valves, and plug valves. All of these facilities are available at competitive prices through local marketing agencies.

There has been extensive construction of large pipelines on the Pacific Coast during the last decade. As a result, local industry has become well organized and equipped to proceed with such projects. Firms from outside the local area may also be attracted to compete for the work connected with this very large job.

Project Planning

A study of the resources available to serve the aqueduct project has brought attention to the possibility of including several alternative designs of pipe and of pipeline joints in the calls for bids. This will permit a substantial number of manufacturers and contractors to compete for the work. The following procedures have been selected to serve to stimulate competitive bidding and to obtain quality construction:

1. Only those types of pipe which have been used successfully on major water supply projects in the past will be acceptable for use. A high-quality pipeline can be constructed if the types of pipe used are limited to those for which there is a substantial history of successful service.

2. All types of pipe that qualify for use under the provision stated above, and in addition appear to be competitive from the standpoint of cost of the project, will be included in the specifications for the construction. The cost of the pipe will amount to about 70 per cent of the total cost of the construction. It is essential to stimulate competition for this part of the work.

3. For the purpose of calling for bids, the total work has been divided into several units. Each of the units will amount to a multimillion-dollar contract, large enough to attract the larger firms. Bids for the various units of work will be called at intervals in the scheduled construction period as plans and specifications are completed. Under this procedure, the work can be started earlier than if the call for bids were postponed until designs and specifications for the entire project could be completed.

4. Each construction contract will call for both the furnishing of the pipe and the installing of the pipeline. This will provide opportunities to use the amounts bid for completed sections of the aqueduct as a basis for awarding the contracts. Competitive bidding under this plan, by which pipe manufacturers quote to, and are paid by, installing contractors, is proving to be vigorous.

5. The construction time for the aqueduct has been scheduled at 3.3 years. Several pipe manufacturers are in a position to service the entire project within such a period. Also, several construction firms are in a position to service the entire project in that time. Under this arrangement and with proper spacing of calls for bids, it is expected that good competitive bidding will be maintained throughout.

6. Three basic types of pipe will be included as alternatives in the specifications: [1] portland cement–mortar-lined and -coated steel pipe (Type S). [2] modified prestressed-concrete cylinder pipe (Type M); and [3] prestressed-concrete pipe (Type C). Other types of pipe that would produce a high quality job are available. They have not been selected for inclusion as alternatives because it does not appear that they would be economically competitive.

Type S Pipe

Type S pipe will consist of a steel cylinder lined with portland cement mortar, wrapped with a circumferential steel reinforcing bar under measured tension, and coated with portland cement mortar. The mortar lining will be ¾ in. thick and the coating will cover the reinforcing rod ¾ in. Of the total steel in the pipe wall, 80 per cent or more will be contained in the steel cylinder, and 20 per cent or less in the reinforcing bar.

The pipe will be designed to support the internal pressures resulting from hydrostatic head and the external loads arising from earth cover and live loads. The calculations used to determine the thickness of the steel cylinder and the size and spacing of the circumferential bar reinforcement will be based on a definite relationship between the stresses in these steel components. This relationship requires that the tensile stress in the bar exceed the tensile stress in the cylinder by the difference between the minimum yield stresses of the two types of steel. Because of this relationship, the two steel components will reach their yield stresses simultaneously under internal pressure load. The pipe will be designed so that the internal pressure that will produce yield stresses in the steel will be equal to 2.25 times the working pressure.

The thickness of the steel cylinder and the quantity of reinforcing rod will generally vary with the hydrostatic head to which the pipe will be exposed in service. An exception to this principle will be at locations where the hydrostatic head is less than 280 ft. At these locations external loads will govern the design of the pipe, and it

will contain more steel than is required to support internal pressures.

A further requirement for the design of the pipe will limit the strain that may be produced in the wall by internal pressure. This requirement will serve to prevent damage of the mortar lining and coating that would result from excessive deformation. The change in stresses in the steel components of the pipe produced by working pressures will not exceed 20,000 psi.

The safe external load will be taken as the computed buckling load for a combination of the steel rod and steel cylinder acting compositely, without regard to the mortar lining and coating. Tests of this pipe have shown that the pipe wall will be several times stiffer than would be indicated by the moment of inertia of a composite section through the rod and cylinder. Thus, the factor of safety against buckling of the pipe under external loads should be satisfactory.

Tests of Type S pipe have also demonstrated that the pipe wall is several times as stiff as is the wall of a steel cylinder having an equivalent weight of steel per foot of length. Therefore, less steel will be required in the pipe, where lower hydrostatic heads prevail and where external loads dictate the design, than would be required for a steel cylinder pipe not equipped with rod reinforcement and mortar lining and coating. The economy in the use of steel that will result from the use of Type S pipe, as compared to unreinforced-steel cylinder pipe, will be very substantial.

Specifications for Type S steel cylinders permit the use of either ASTM-A-283 Grade C steel plate with a minimum yield stress of 30,000 psi or API Grade X-42 steel plate with a minimum yield stress of 42,000 psi. The specifications also require the use of ASTM-A-15 hard-grade steel rod with a minimum yield stress of 50,000 psi for the reinforcing rods of the pipe. With this combination of steel components, pipe for the new aqueduct will both meet the design criteria and use steel very efficiently. A-283 steel can be used at locations where lower hydrostatic heads are encountered and thus where buckling loads govern design; X-42 steel, at a premium price, can be used to advantage where the higher hydrostatic heads are encountered and internal pressures govern. The design of this pipe will require only about 80 per cent of the steel that would be required by the usual design of unreinforced-steel cylinder pipe.

Type M Pipe

The construction and the criteria for the design of the Type M pipe will be the same as those for the design of Type S pipe, with the following modifications:

1. Of the total steel in the wall of Type M pipe, 40–80 per cent will be included in the steel cylinder, 20–60 per cent will be included in the reinforcing bar.

2. Only ASTM-A-283 Grade C steel plate with a minimum yield stress of 30,000 psi will be used in manufacturing the steel cylinders of Type M pipe.

As a result of these modifications, Type M pipe will have a lighter steel cylinder and a heavier bar reinforcement than will the Type S pipe, and, because of conditions in the pipe industry, Type M pipe will be supplied by firms engaged in the manufacture of concrete pipe, whereas Type S pipe will be supplied by firms engaged in steel fabrication.

Except for the modifications of design criteria previously explained, all

that has been said herein about Type S pipe also applies to Type M pipe. The total quantity of steel required for the project will be about the same with Type M as with Type S pipe.

Type C Pipe

Type C will have four principal components:

1. A welded–sheet steel cylinder
2. A core consisting of the sheet steel cylinder embedded in a concrete cylinder
3. Reinforcement consisting of high–tensile strength wire, wound helically on the outside surface of the core at a predetermined tensile stress
4. A coating of dense concrete cast against the outside surface of the core.

The pipe will be manufactured in conformance with AWWA C301 with a few modifications. The internal bursting pressure for the pipe will be three times the magnitude of the working pressure. The pressure that produces zero compression in the core will be not less than 1.25 times the magnitude of the working pressure. The design of the pipe will be such as will prevent the occurrence of tensile stresses in the core under any specific combination of external static trench loads and internal operating pressures.

Field Girth Joints

Although double-weld, bell-and-spigot girth joints have been used extensively in the past in the construction of large-diameter steel pipelines, consideration is now being given to the use of single-weld, bell-and-spigot girth joints. Recent bids on large-diameter pipelines in the Pacific Coast area have indicated a significant economic advantage in the use of rubber gasket girth joints for joining pipe sections in the field, as compared to the use of double-weld lap joints.

Tests of the single-weld, bell-and-spigot girth joint to determine its tensile strength were recently arranged for by the district and prosecuted by a local steel fabricating firm. The test results indicated that single-weld, bell-and-spigot girth joints, on large-diameter steel pipe, support bulkhead loads produced by internal pressures that stress the pipe circumferentially to the ultimate strength of the steel. Furthermore, as failure at the joint results from rupture of the steel plate rather than from failure of the weld, the tests indicated that a second weld would not have increased the tensile capacity of the joint.

In the specifications for the aqueduct, single-weld, bell-and-spigot girth joints will be included as an alternative to rubber girth joints for Type S pipe only, whereas rubber gasket girth joints will be specified without alternatives for Type M and C pipe. The steel cylinders for Type S pipe are thick enough, and, therefore, strong enough, to support an adequate tensile joint, whereas the steel cylinders for Type M and C pipe are too thin. Where constructed with rubber gasket girth joints, the hydraulic forces due to changes in alignment of the pipeline will be supported by concrete anchors. Where constructed with welded girth joints, these forces will be supported by the pipeline itself.

Backfill

Excessive deflection of the types of pipe specified for the aqueduct is apt to rupture the mortar and concrete components. It is essential that the backfill provide for the development of substantial side support for the pipe at small deflections. The specifications for the aqueduct will require that if the excavated material is not suitable for backfill, imported backfill will be

placed properly around the pipe from the bottom of the trench up to the springline of the pipe. This imported backfill will be a granular material that passes definite sieve requirements. In order to prevent the pipeline from being forced out of shape while the trench is being backfilled, the specifications will require that the pipeline be bulkheaded and filled with water under a minimum hydrostatic head of 50 psi during backfilling operations.

Bid Experience

On Jun. 12, 1959, bids were opened for the construction of a unit of the aqueduct. Bids on this unit, which is approximately 34 mi long, ranged from $15,000,000–$18,000,000. All ten bids received were based on the use of Type S pipe. Three bids were based on the use of rubber gasket girth joints, one was based on the use of both welded and rubber gasket joints, and six were based on the use of field-welded girth joints. A comparison of the bids indicated vigorous competition for the work between materials suppliers and also between installing contractors.

All of the bids that were submitted were based on the use of the same type of pipe from the same source of supply. It is not true, however, that competition between the various pipe manufacturers for the business of supplying the pipe was unsatisfactory. It is known that both steel and concrete pipe manufacturers engaged in a serious competitive contest for the work. In the end, a manufacturer of steel pipe submitted the lowest quotation.

In order to evaluate the bids received, the low-bid cost of this unit of the aqueduct has been compared with the cost of 50 other major pipeline construction projects in the western part of the United States. For this comparison an index was used, consisting of the cost per foot of length per inch of inside diameter of pipeline. The index as calculated for the aqueduct proved to be about 85 per cent of the norm for the other projects.

Conclusion

It is believed that the procedures described in this article will result in a significant overall economy in the construction of the aqueduct. Although the pipe that is to be used is sufficiently rigid to require special care in backfilling, the designs permit the use of a minimum quantity of steel. With rigidity resulting from the mortar lining and reinforced-mortar coating of Type S and M pipe, the requirements for supporting external loads on the pipe can be met with very little steel in excess of that required to support internal pressures.

The alternative types, lengths, and designs of pipe sections, which will be incorporated in the specifications for the aqueduct, should permit each contractor to bid under his most favorable competitive condition, and high-quality construction at fair prices is anticipated. The East Bay Municipal Utility District was gratified by the result of the first call for bids.

Acknowledgment

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Development of the Upper Colorado River

Ernest O. Larson

A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Ernest O. Larson, Regional Dir., Region 4, US Bureau of Reclamation, Salt Lake City, Utah.

GLEN CANYON Dam is the largest concrete dam now under construction in the United States. Larger in volume of concrete than Hoover Dam and almost as high, it will be one of the highest dams in the world and will create the second largest reservoir in the United States. The Glen Canyon power plant will be one of the ten largest in the United States. Estimates indicate that at present price levels it will cost about $325,000,000 to build the Glen Canyon Dam and power plant. With its large storage capacity and power plant, the Glen Canyon storage unit is the key to the future development of the Upper Colorado River Basin.

The program for development and use of the water resources of the Upper Colorado River Basin, at an estimated cost of about one billion dollars, is truly basinwide. Public Law 485, authorizing the Colorado River storage project and participating projects, was signed by President Eisenhower on Apr. 11, 1956. Authorized for construction as the initial phase were four storage units, of which Glen Canyon is the principal unit, and eleven participating projects for water to be used for the irrigation of farm land and for municipal and industrial expansion.

History

The Upper Colorado River Basin is a plateau land in the heart of the intermountain West, including the southwestern portion of Wyoming, the western half of Colorado, the eastern half of Utah, the northwestern corner of New Mexico, and a small section of northeastern Arizona (Fig. 1).

The Upper Basin has been a dry and formidable area. It has been late in exploration and, up to now, slow and limited in settlement and development. Early pioneers largely avoided the area in their treks westward. For the most part, the Colorado and Green rivers in the upper basin were not explored and mapped until 1869 when John Wesley Powell made his famous river trip through the deep, winding canyons.

Mining activities on the fringes of the Upper Basin marked the early history. Later, stock raising and irrigation of the bottom lands along the streams came to predominate. Where it could be done easily, streams were diverted and used for irrigation, but on a small scale. Two large and successful projects were built by the Bureau of Reclamation prior to World War I, but since that time only three relatively small irrigation projects have been undertaken. By comparison, elsewhere in the seventeen western states, the Bureau of Reclamation built many large and important projects after 1920.

By 1940, the 110,000-sq mi Upper Colorado River Basin, which is about the size of the states of Illinois and

Wisconsin combined, had only four cities of more than 5,000 population; Grand Junction, Colo., with a population of 12,500, was the largest.

Resource Development

The Upper Colorado River Basin has many resources awaiting development and use. During and following World War II, there has been considerable development of uranium, vanadium, coal, oil, gas and other mineral resources. But this only the forerunner of the much greater progress that is expected to take place when the Colorado River storage project and participating projects are built.

The Upper Colorado River Basin is rich in resources. It has the water of its rivers. It has canyons with potential dam sites, where water can be stored and hydroelectric power produced. It has lands that can be farmed under irrigation. It has petroleum, natural gas, and about one-third of the nation's known coal reserves. It has vast areas of oil shales and rare hydrocarbons. It has the raw materials to supply many strategic metals. It has uranium and other atomic ores. It has mountains of phosphate rock for fertilizer production and other needed nonmetallic ores.

The key to the development and use of these land and mineral resources is the availability of water and power. The Upper Basin program will make available the needed water and a sizable block of the needed power under a long-range plan in which all reimbursable costs will be repaid by the beneficiaries with interest on all but those costs allocated to irrigation. The costs allocated to irrigation do not bear interest under federal reclamation law. Approximately 98 per cent of the billion-dollar estimated cost of the presently authorized works will be reimbursable and about 66 per cent will be repaid with interest.

Colorado River Compacts

The rights of the Upper and Lower basins to the use of Colorado River water are set forth in the Colorado River Compact of 1922, which is a complex document that cannot be dis-

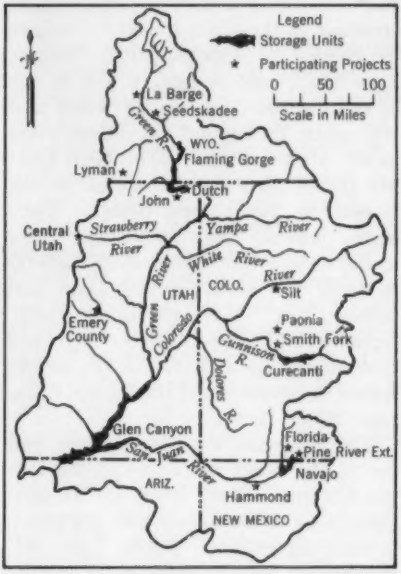

Fig. 1. Colorado River Storage Project Area, November 1956

Points discussed in the text are shown above.

cussed in detail here. By the subsequent Upper Colorado River Compact of 1948, the Upper Basin states (Colorado, New Mexico, Utah, Wyoming, and Arizona) divided among themselves the water allotted the Upper Basin under the 1922 compact. The Upper Basin's right to 7,500,000 acre-ft per annum under the 1922 com-

pact approximates one-half the average flow at Lee Ferry in northern Arizona, the dividing point between the Upper and Lower basins. The Upper Basin's right is conditional to the delivering of a base flow to the Lower Basin of 75,000,000 acre-ft at Lee Ferry in consecutive 10-year periods.

Because the virgin flows of the Colorado River at Lee Ferry are erratic and vary annually from as little as 5,500,000 acre-ft to as much as 25,000,000 acre-ft, large holdover storage reservoirs must be built if the Upper Basin states are to be able to make full use of their right to the residual, or the erratic half of the flow.

Storage Project

This explains the initial authorization of four storage units of the Colorado River storage project. They are the Glen Canyon unit on the Colorado River in Arizona and southern Utah, the Flaming Gorge unit on the Green River in northeastern Utah and southwestern Wyoming, the Navajo unit on the San Juan River in northern New Mexico and southern Colorado, and the Curecanti unit on the Gunnison River in western Colorado. Holdover storage in the large storage reservoirs thus will make possible new diversion and beneficial consumptive use of water on the participating projects taking water from tributary streams throughout the Upper Basin. In addition, the hydroelectric-power plants at the storage dams will produce power to help meet pyramiding regional needs and to provide revenues from power sales which will assist in the repayment of the costs of the entire program.

The significance of the storage units in the Upper Basin development is clearly evident. Therefore, construction of the storage units was begun first. Construction of Glen Canyon Dam on the Colorado River near Lee Ferry was started late in 1956, and it is scheduled for completion and the first production of power probably in 1963. At the Glen Canyon Dam site, the diversion tunnels are now completed, and the river is diverted. Work is underway on the foundation excavation and on the erection of the highline cableways, concrete batch plant, aggregate plant, and other facilities so that the first concrete can be placed early this fall. Glen Canyon Reservoir will store 28,000,000 acre-ft of the 35,000,000 acre-ft of storage provided by the four initially authorized storage units. The Glen Canyon Power Plant will provide 900,000 kw of installed generating capacity of the nearly 1,200,000 kw at the four storage units.

Prime contracts were awarded in June 1958 for the construction of two other storage units—namely, the Flaming Gorge Dam on the Green River in northeastern Utah near the Wyoming state line and the Navajo Dam on the San Juan River near Farmington, N.M.

Flaming Gorge Dam will be a concrete-arch dam about 500 ft high with a power plant of 108,000 kw of installed capacity. The reservoir created by the dam will store almost 4,000,000 acre-ft. At the present time, the heavy road construction at the dam site has been completed, the single diversion tunnel has been excavated and is now being lined with concrete, and the river will be diverted in September 1959. The total cost of the Flaming Gorge unit will be about $65,000,000.

Navajo Dam will be a tremendous earth and rockfill structure. With 26,300,000 cu yd in the embankment, it

will be the second largest to be built by the Bureau of Reclamation. About 5,000,000 cu yd of materials have now been placed. The Navajo storage unit will cost about $42,000,000 and will store more than 1,700,000 acre-ft of water.

Construction of the Curecanti storage unit, consisting of three dams and power plants on the Gunnison River in western Colorado, is scheduled to be undertaken in near future years.

Construction was begun on two of the eleven authorized participating projects this year. The eleven authorized participating projects, when completed, will provide supplemental water supplies for 232,000 acres of presently irrigated land that is short of water nearly every year. It will also supply water to about 115,000 acres of dry land. Irrigation of new lands, however, is not scheduled for several years. The authorizing legislation earmarked 25 additional participating projects for study as to feasibility. In future years and as demands arise, such projects could bring about the irrigation of more than 1,000,000 acres of supplemental and new land areas. In addition, plans for the participating projects will include, where needed, the supply of water for municipal and industrial development.

Project Authorization and Terms

The plan and authorization of the Colorado River Storage Project is different from the usual water resource development plan. It was planned as an integrated, long-range basinwide program in close cooperation with state and local interests, the Upper Colorado River Commission, and the federal agencies concerned. Fundamentally, the large storage units of interstate significance will be operated and maintained by the Bureau of Reclamation, in accordance with the 1922 and 1948 compacts. Individual participating projects are to be operated by water user organizations with the use of the water governed by state laws and the compacts.

The authorizing act has several significant and unique provisions which are worthy of mention. There is authorized a separate fund in the Treasury of the United States to be known as the Upper Colorado River Basin Fund for carrying out the reclamation provisions of the act. The Congress makes appropriations into the basin fund and all income from the irrigation, municipal, and industrial water users, from the sale of power, from other minor sources, is credited to the basin fund for repayment of reimbursable costs. Annual reports are required to be submitted to the Congress detailing the expenditures from the fund and the anticipated revenues into the fund to show that the repayment plan is currently solvent. The act also provides for the apportionment among the upper basin states of surpluses accruing in the Colorado River Basin Fund to be available for appropriation by the Congress for the construction of additional projects.

The act provides that the Secretary of the Interior is authorized and directed to investigate, construct, operate, and maintain public recreation facilities and facilities to mitigate losses of, and improve conditions for, the propagation of fish and wildlife. Funds appropriated for these purposes are to be nonreimbursable. By this provision, recreational development on reclamation reservoirs becomes a fully recognized benefit of local and nationwide significance.

The program for the Upper Colorado River Basin was planned and authorized, and is now being carried out, as a long-range, coordinated development which will give the Upper Basin states the opportunity to make full use of their shares of the waters of the Colorado River. It is a plan that permits the development and use of water for all purposes, now and in the future, as circumstances change and needs evolve.

Expected Benefits

The benefits to the upper basin states and to the nation will probably surpass anything that can be predicted with certainty—for such has been the history on other federal reclamation programs. Some of the benefits which can be anticipated are:

1. Water to supplement the present scant supply which retards the growth of many areas in the Upper Basin, and, when appropriate, water for new lands, to produce food to meet the needs of both an increasing population and a higher standard of living.

2. Crops from irrigated land to create a better balance in the use of ranges by providing winter feed, thereby increasing the carrying capacity of range lands without destructive overgrazing

3. The growing of a variety of crops needed by the region and the nation

4. The creation of irrigated oases in the desert, which will serve as centers for industrial development

5. The making available of water for industrial expansion and future population growth

6. Power for remote parts of the region to develop valuable minerals and other resources now virtually untouched.

Location and Development of Ground Water Supplies

—Paul J. Kleiser—

A paper presented on Feb. 5, 1959, at the Indiana Section Meeting, French Lick, Ind., by Paul J. Kleiser, Cons. Engr., Kleiser & Assocs., Terre Haute, Ind.

THERE was a time, not too many years ago, when location and development of ground water supplies were relatively simple in Indiana. If a municipality or industrial firm needed more water, a well driller merely put down a hole at a location convenient for the owner and usually got the desired quantity of water. Today the problem is not quite so simple.

Indiana towns, cities, and industries have been expanding so rapidly in recent years that in many places the water demand is becoming greater than the available supply. Although test holes are still the safest and most reliable means of securing information, the cost of drilling test holes has so increased that this method is of questionable economy in areas where ground water is scarce. Consequently, ground water development experts have taken a few lessons from the oil industry and are now making rather extensive use of other methods of locating and developing underground water.

Geologic Data

In spite of all the new developments, however, the basic starting point in all such work is a careful study of the general geology of the area. Geologic studies of the underground conditions in Indiana have been made by many agencies, and a considerable amount of information is available. In recent years USGS and the Indiana Division of Water Resources have been compiling a detailed inventory of underground data from reports of well drillers, engineers, municipal officials, and any other likely sources. These agencies have also established a number of stations in Indiana where measurements of the water table are regularly made. A State Department of Conservation publication (*1*) probably contains the most comprehensive compilation of data on ground water conditions in Indiana that has yet been grouped in one volume. If similar statewide publications were brought up to date and made available, it would be a thing of great service to all water supply men. Ground water resource bulletins, prepared by the State Department of Conservation and USGS and covering several counties, are also available; these volumes represent many hour of work in compiling the data.

Well Records

After geologic data have been gathered, the next step is to get all available data from any existing wells in the area. If there are a number of wells, and if proper records are available, this information can be quite valuable.

Unfortunately, the records of many of the existing wells in any particular area are often either lost or incorrect. In the past many drillers have even regarded the log of a well as personal property—to be destroyed rather than given to a competitor or a public agency. Fortunately, this attitude is changing, and fairly accurate information is now being obtained. It is very likely that most states will pass laws in the near future requiring drillers to furnish logs, together with formation samples and records of production tests. Until that time arrives, however, one has to depend upon the reliability and good faith of well drillers.

All available well records must be studied to determine the elevation of the water table, the depth and thickness of water-bearing formations, the chemical quality of the water, and the quantity produced when the well was originally drilled and at the present time. If any abandoned or unproductive water, oil, or gas wells are located in the area, their records can also be of value.

Electric Logs

Considerable information about underground conditions can be obtained from an electric log, and at relatively little expense. Electric logs were developed and first used by petroleum and gas companies. In recent years these methods have been used by water well drillers for underground explorations. The basic principle of electric logging is the measurement of two electrical quantities, electrical resistance and electrical potential. The electrical resistance of most formations is determined entirely by the chemical nature of the water in the formations penetrated. Naturally, the electrical resistance varies appreciably from one formation to another in a drill hole.

The equipment for making resistance measurements is relatively simple. It consists essentially of an electrode attached to an electric cable which is lowered into the drill hole by means of a reel or hoist. The upper end of the cable is connected to a recording instrument at ground surface. The cable passes over a calibrated pulley which drives a strip chart upon which the resistance measurements at various depths are automatically recorded. The measurements are made in ohms, which are the basic unit of electrical resistance.

Potential measurements, if desired, can be made with the same recording equipment. A voltmeter is connected in the circuit between the electrode in the drill hole and a ground iron set at the ground surface. Measurements are made in millivolts (0.001 v) and are recorded simultaneously with resistances on the same strip chart.

Light-weight, portable field units are available that are capable of logging wells 500 ft deep or less. The entire unit with cable weighs less than 100 lb and can be set up in a few minutes. No outside source of power is needed, as the unit contains its own batteries.

Correlation of resistance and potential measurements with water quality and with water-bearing formations requires experienced judgment and should be done only by persons familiar with such analyses. The relationships may be very distinct and easily recognized, or they may not be so readily apparent.

An electric log cannot, obviously, be made in a cased hole. The equipment can only be used in a rock hole or in a well drilled by methods that do not require the use of metal casing.

The value of electric logging was well illustrated at Staunton, Ind., where attempts were being made to develop a public water supply system for the community. The geologic and available well data were very discouraging. The few existing wells in the area were about 200 ft deep in rock formations that yielded very little water. Fortunately a copy of an electric log of a well drilled in the area some years before by an oil prospecting firm was available. A study of the log indicated that there were no important water-bearing formations in the area but that there were possibly numerous small quantities of water in the various sandstones scattered through the drill hole. It was suspected that a comparatively deep hole might serve to gather all these small sources of water into a sufficient quantity for a reasonably dependable supply for a town the size of Staunton. Fortunately the suspicion was confirmed. It was only necessary to drill one hole to locate sufficient water, but that hole was 380 ft deep. Without the assistance of the electric log, considerable money could easily have been wasted in drilling 250-ft test holes, which was the greatest depth previously penetrated for a source of water supply. After the well was completed an electric log was made of the uncased portion of the hole. This log substantiated the information obtained from the electric log of the oil well and showed that small quantities of water were being obtained from at least twelve different places in the sandstone.

Seismic Method

When there are no available wells or bored holes in the area, modern prospectors make use of either seismic or electrical-resistivity methods for locating ground water formations. In recent years the electrical-resistivity method has become much more popular than the seismic method.

The seismic method measures the velocity of a wave instigated by an impact on the ground or the explosion of a small charge of dynamite buried beneath the surface. A simplified field setup for seismic determinations requires the placing of an explosive in a 6-ft shot hole and distributing the seismometers or detectors at equal intervals in a straight line from the shot point. The spacing is determined by the character of the subsurface material and by the depth to be investigated. The most satisfactory results are obtained with instruments that have twelve or more detectors. Vibrations pass slowly through loosely compacted material, and more rapidly through dense material.

When the shot is fired in the shallow shot hole, the vibration waves move out in all directions, forming a curved wave front. At the instant that the wave front reaches the seismometer closest to the shot hole, the instrument is at a point tangent to the wave front, and is oscillated. At the same instant, the wave front also reaches a point beneath the shot point approximately the same distance as that between the first seismometer and the shot point. This relationship is true throughout the line of seismometers. It follows, therefore, that if the seismometers were all placed so that they were equidistant from the shot point, and in a circle, the arrival times of the curved wave front at each seismometer would be simultaneous. On any survey, this configuration is usually duplicated numerous times at various locations to determine the average velocities of the top, or first, material

encountered. The arrival times of the wave front are measured in thousandths of a second. These times are plotted on a time-distance chart against their corresponding distances from the shot point, and the velocities and depths of velocity changes are computed and correlated with known geologic conditions.

The seismic method is a good one for locating depth of rock, but it has generally been superseded in the Middle West by the electrical-resistivity method for the location of test well sites.

Electrical Resistivity

The electrical-resistivity method has two important advantages over the seismic method in water prospecting: [1] it is considerably less expensive, and [2] it comes closer than other methods to giving direct hydrologic information, because it depends largely on the electrical conductivity of the ground water itself. The important feature of the electrical-resistivity method is that the coarse and clean materials, such as sand and gravel, offer higher resistance when saturated than do saturated fine-grain materials such as silt and clay. Another feature which is not quite so important in Indiana is that by this method salt water can be readily detected and located.

Briefly, the resistivity method consists of driving of four stakes centered on a given spot, with the stakes equally spaced along a straight line. An electric current is passed between the two outer stakes and the voltage drop across the two inner stakes is measured directly on an instrument reading in ohm-centimeters of apparent resistivity. Generally speaking, the spacing of the stakes is approximately the same as the depth to which the readings are taken. This procedure is repeated until the entire area under investigation is covered. The field work is not difficult and an experienced crew of two men can usually make about twelve depth profiles per day, covering 25 acres. The data obtained are initial readings known as "apparent resistivities." From these data a resistivity map of the area may be prepared. This is similar to a topographic contour map of the ground surface except that the resistivity readings indicate underground formations. The interpretation of the data is extremely important and requires a capable and experienced analyst to translate the information. A few illustrations bear out this point. A layer of dry sand at ground surface makes the method almost useless; this is particularly true in some areas in northwestern Indiana near Lake Michigan. A layer of water-bearing sand and gravel near the surface may screen out a good water-bearing formation below it or confuse the results. Limestone bedrock gives much the same kind of reading as sand gravel deposits and may also confuse the results. Thus the resistivity method has real value only when interpreted by an expert with ample experience.

By correlating the data obtained from a resistivity survey with other known data, usually with just one test hole in the area, an expert can select the most desirable locations for wells. This procedure eliminates to a very great extent the blind, haphazard drilling of numerous test holes.

Formation Samples

The next step in a location program is the drilling of test wells to locate the best water-bearing formation and to determine the quality and quantity

of water that can be produced. Selection of the type of drilling is determined by cost, type of information desired, and particularly by the accuracy of formation data desired. In the commonly used and inexpensive cable tool method of drilling, a pipe is driven into the ground and bailed samples are obtained. In the jet, or hollow-rod, method of drilling, a pipe is driven into the ground to obtain washed samples. The rotary method of drilling does not drive any pipe, and hence an electric log can be run to remove some of the subjectivity in estimates of the quality of a formation. The washed or bailed samples should give a reasonable picture of the formation if studied by a skilled operator. Unifortunately, well drillers do not have a uniform standard or code for describing formations and a great deal depends upon the interpretation of each particular driller. Cored samples, which can be obtained by all three methods of drilling, give the most accurate information on the formation. Upon completion of the test well or wells, the driller should furnish a true set of formation samples, a complete log of the well, pumpage data, and water samples for chemical analysis.

Value of Electrical Methods

The value of electrical-resistivity surveys was demonstrated quite clearly when a large aluminum company decided to build its new plant in the vicinity of the Ohio River. One would naturally assume that ground water would be no particular problem right on the Ohio River, but the preliminary investigations indicated that it would not be an easy matter to obtain ground water at the rate of 20,000 gpm. The plant's ultimate total requirement of both ground and surface water was to be 200,000 gpm. General geologic and old well drillers' records were very discouraging, and a resistivity survey was made as the first step in the program. It was soon learned that the property available for the plant was practically devoid of ground water. The only area that had any possibility of yielding such a large quantity of ground water was a narrow band less than 500 ft wide along the bank of the river, and the higher-yield sections of this band were not too numerous. The resistivity data were further substantiated by the drilling of three test holes and nine pilot holes. Observations of the pilot wells and one pumped test well indicated that wells of 1,500 gpm could safely be obtained with a spacing of 200 ft. Expert analysis also indicated that 2,500-gpm wells with 100-ft spacing could be depended on as a maximum program if needed. It is obvious that the cost of this survey was far less than the cost of drilling the many 6-in. test holes or 2-in. prospect holes it would take to cover 600 acres. Furthermore, a few successful test holes alone would not have revealed the limited areas of good water-bearing formations.

From the foregoing example one can readily see why electrical methods are assuming more and more importance in ground water location procedures, particularly where ground water is difficult to locate.

Development

In the matter of ground water development, on the other hand, there have been no startling new advances in recent years. Many of the wells in Indiana are finished in sand and gravel formations. As is well known, the

selection of the proper screen size is extremely important in such areas, and this is where the reliability of formation samples is put to the test. Each sample is passed through a series of sieves and the percentage of the total sample retained on each sieve is plotted against each sieve opening size. The resulting graph is known as a sand analysis curve and is used to determine the optimum screen opening.

There are several methods of interpreting sand analysis data for the design of well screens. If a well driller is not equipped to make an interpretation he may send the sand analysis curves to any one of several manufacturers of well screens, and these agencies will make the interpretation and recommend the proper screen design. Better results are usually obtained, however, if the analysis is performed by, or under the direct supervision of, an engineer or geologist who is familiar with the sampling techniques of the drillers under his control. In this way he is better able to judge the representative quality of the samples and temper his recommendations accordingly.

The same procedure generally holds true for gravel-walled wells. Such wells have their greatest usefulness in fine-sand formations, and the sand analysis data are important in the selection of the proper size of gravel to provide the most effective screening of sand and still permit the development of the maximum quantity of water from the formation.

The next step is to run an aquifer performance test to determine how much water can be produced by a properly constructed well during a dry period, and to determine generally how many wells will be required for a given yield, and what their spacing should be for most economical operation.

Aquifer Performance

The aquifer performance test setup, in its simplest form, consists of a pumping well with two pilot wells located 50 ft and 100 ft away from the pumping well. This combination usually gives the best results with the least expense. The pumping well is operated for perhaps 12–72 hr. The water level in the pilot well is measured for perhaps 24 hr before the pumping test is begun and for a while after it is terminated.

If a large quantity of water is required, or it is necessary to determine the amount of infiltration from a nearby stream or lake, a more elaborate pattern of pilot wells may be required. Such a pattern might include as many as 6–8 pilot wells spaced around the pumping well up to distances of several hundred feet. The pattern of placement should be so specified—by the hydrologist who is to interpret the results of the pumping test—that maximum results may be obtained from the investment in the test.

The duration of the test is affected by the nature of the underground formation. If there is an artesian condidition, in which the water level actually stands above the top of the formation, then a 12-hr pumping test might be sufficient. If, however, the water level stands within the formation, then a test as long as 72 hr may be required. In an artesian well, the development of a cone of depression requires only a pressure change, which is almost instantaneous. When a well is pumped under water table conditions, the development of the cone of depression

requires actual removal of the water above the cone, and the time required to remove the water is much greater.

A competent hydrologist can take the data from a pumping test and determine the amount of water that can be pumped continuously from a given site for perhaps 100 days without rainfall. He can also compute interference between wells and the best spacing of wells for a given production.

Quality and Treatment

After a source of ground water has been found, it is important to make pilot plant tests of the water in order to determine the best method of water treatment to be used. Such tests are particularly valuable in the matter of iron and manganese removal. For instance, in the development of a new water supply well for the city of Frankfort, Ind., pilot plant tests proved conclusively that the pressure aeration process would be successful and this process was used in the final design of the well. The final design meant a material saving over the standard open aeration process of iron removal. It is of interest to note that four of nine recently designed iron removal plants did not require the open aeration process for satisfactory iron removal.

It is well known that the detention period after aeration is a prime factor in the removal of manganese and hydrogen sulfide gas. Pilot plant tests can determine quite accurately what the optimum detention period should be. This was very well demonstrated in a project at Goodland, Ind., where it was found that aeration alone was not successful in reducing the hydrogen sulfide content to a tolerable amount. Pilot plant testing showed the best combination of aeration and detention needed to reduce the hydrogen sulfide content enough that chlorination would then give water of a satisfactory quality.

Another point that should be brought out is that the problem of well location must always be considered in terms of its sanitary aspects—particularly that of proximity to sources of surface pollution. The Department of Health of Indiana has established certain standards to be used as safeguards and these standards should be followed where possible.

Reference

1. *Ground Water in Indiana.* Publication No. 133, Indiana Department of Conservation, Indianapolis, Ind. (1935).

Survey of Water Use and Rate Structures at Bethlehem

—*Eli Schwartz, Francis M. Brady Jr., and Sidney Silver*—

A contribution to the Journal by Eli Schwartz, Assoc. Prof. of Finance; Francis M. Brady Jr., Asst. Prof. of Accounting; and Sidney Silver, Instructor, all of Lehigh Univ., Bethlehem, Pa.

IN the fall of 1957, the city officials of Bethlehem, Pa., consulted one of the authors regarding the organization of a survey team to study the operation of certain aspects of the city's water department. Much of the material that follows has been taken from the report of that survey.

The objectives of the survey were:

1. To test the adequacy, efficiency, and comprehensiveness of the billing lists
2. To obtain comparisons of consumption and average billings from the domestic water users billed on a flat-rate basis and those on a metered basis (approximately one-third) in order to analyze the rate structure and, more important, in order to project water consumption and sewage capacity needs for the future
3. To analyze and review the financial position of the water department
4. To study the adequacy and equity of the prevailing rate structure.

The authors believe that the data resulting from the study of water consumption patterns are of general interest and usefulness. For this reason, the greater part of this article is concerned with the presentation of these data; the detailed recommendations relating to other phases of the survey are summarized.

Recommendations Based on Audit

The main purpose of the water bill audit was to determine whether every user of city water was on the billing lists and if all commercial users were on metered rather than flat-rate billings. The audit consisted basically of a comprehensive check of the water billing lists against the city directory, tax rolls, and recent building permits.

In view of the rapid growth of the city in the past 7 years, the mobility of the population, the complexity of street geography, and the multiplicity of building construction and placement, the audit revealed fewer errors and discrepancies than might have been expected. The survey team did, however, make several recommendations to strengthen control and to obtain greater efficiency by placing more information and control in the hands of the supervisor of the central billing system. The most important of these suggestions was that the supervisor be provided with a list of building permits and new building inspections. Space was provided for entering the amount and time of the county assessment and the time when each building was occupied and began using water. These lists would then be used as an automatic check for the speed with which

new construction was placed on the water billing lists.

The second major aspect of the study consisted of an analysis of current costs and revenue and of a projection of future fiscal operations of the city water department. It was deemed desirable to obtain information on the characteristics and patterns of consumption among different types of users and their average water bills under the existing rate system in order to move toward a more equitable rate structure. This last aspect of the study involved the use of a detailed sampling and survey technique.

TABLE 1

Extract From Study of 75 Randomly Selected Second Meter Readings, October 1958

No. of Persons in Household	Account No.	Usage *gal*	Time Between Readings *days*	Projected Yearly Usage *1,000 gal*	Usage During Previous Year *1,000 gal*
One	5923	3,180	42	28	33
Two	5908	401	42	34	46
	3759	1,771	47	137	116
	6613–10	258	41	23	39
	6603	862	41	76	80
	6599	450	41	40	34
	6596	593	41	53	63
	5919	292	42	25	23
	5913	310	42	26	27
	2628	455	40	41	39
	3716	821	55	55	40
	4226	246	45	20	31
	2046	954	40	87	70

Fiscal Analysis

An important part of the report on the operations of the Bethlehem Water Department consisted of a forecast of revenues and expenses for the future. Because all of the survey suggestions have not yet been implemented, detailed data on the fiscal position cannot be presented in this article. In general, the report recommended fairly substantial rate increases to cover estimated increases in repair and maintenance costs, increased debt service charges, and repayment of borrowings from the general fund.

It was pointed out that if revenues were raised sufficiently to cover all forecasted costs and to repay the interfund debt in approximately 5 years, it might be possible that the water department would eventually generate a slight surplus. It was believed, however, that any such surplus should be considered minimal in the light of the city's high investment in the water department facilities and capital plant. To some, the question of repayment of an interfund debt may appear to be only of bookkeeping consequence. A significant proportion of water users are outside the city limits of Bethlehem, however. To the extent, therefore, that the general fund supports deficits in the water department, the citizens of Bethlehem are granting a subsidy to outlying districts.

It was obvious that the Bethlehem rate structure would have to be shifted upward because of increased costs,

but a detailed analysis and a survey of water consumption patterns were made in order to determine a more productive and equitable rate structure.

Survey Techniques and Results

It seems that no comprehensive survey of household water consumption patterns has been made since the mid-1930's (*1*). For this reason, it may be of some interest to discuss the sampling technique in detail.

Procedure

Blocks of 20 cards were selected at random from both flat-rate and meter rate billing lists. In the initial sample there were 1,465 meter users and 1,526 flat-rate consumers. The samples were large enough to provide adequate geographical coverage. The sampling crew obtained information on the number of households in each building, the number of people in each household, the number of children of less than 3 years of age, the number of automatic household appliances (clotheswashers or dishwashers), and lawn size (minimum, suburban, large). At metered households, a meter reading was taken.

From the record books maintained by the water department, the annual consumption for the various types of metered households was recorded. As a test, a month after the original meter reading was made, a second reading was taken of 75 accounts selected at random from the original sample. Annual water consumption was then estimated for these accounts and compared with the average consumption of the major metered sample of 1,342 users (Table 1). The results of this check (Table 2) vary by only 1.0 per cent from the major sample, which confirms the accuracy of the water department records. This check was considered necessary because it is customary in Bethlehem to estimate water consumption for the record books over long periods. Also, as will be explained below, the minimum-use level is still fairly high in Bethlehem, and it was possible that meter readers might not consider it important to make accurate periodic readings. Whenever there were wide discrepancies between consumption derived from the record books and the ordinary range of annual consumption because of adjustments for underestimates of prior years, the accounts were deleted from the major sample. Of this group of 423, 89 were later rechecked with a second meter reading giving the actual consumption for the month of October. (October may be considered an average month for water use; whenever the actual consumption for October was extended to an annual basis, the estimated annual consumption fulfilled the expected norms for the type of household concerned.) The results of this test established further proof of the accuracy of the large sample.

TABLE 2

Summary of Results of Study of 75 Second Meter Readings, October 1958

Source of Data	Avg Annual Use—gal		No. of Residents per Family
	Per Capita	Per Family	
Meter books for 1,342 households	18,414	59,495	3.23
Projections from actual readings of 75 households	18,542	58,875	3.17

Meter Rate and Flat-Rate Bills

A comparison of the average annual water bills of 1,526 flat-rate households and 1,342 meter rate households

(Table 3) indicated that the average flat-rate user paid 41 cents more per capita, or about $3.43 more per household, than did the meter users. Both these figures are net of discount, but include meter rentals. The household sizes on the flat-rate sample were somewhat higher on the average, however, which caused a slight upward bias in the average flat-rate household bill. In general, flat-rate consumers paid 8.2 per cent more per capita than the meter users, although it is likely that they characteristics. Although this is not a strictly invariant relationship, it seems applicable to Bethlehem, given a minimum that exceeds the average use in 86 per cent of the metered households.

As average household size varies in each category, and the number of billings in each frequency class were too small to be reliable, a cross-category comparison would not be too useful. The estimate of total consumption should be quite reliable, however.

TABLE 3

Comparison of Domestic Flat-Rate and Meter Rate Water Bills

Type of Unit	No. of Billings in Sample	No. of Households	No. of Residents	Total Net Billing $	Avg Billing per Household $	Avg Billing per Capita $	Avg No. of Residents per Household	Avg Annual Usage per Household gal	Avg Annual Usage per Capita gal
Flat-Rate Sample*									
Apartment houses	44	93	271	1,147.20	12.34	4.24	2.91		
Private homes	1,433	1,433	5,248	28,706.80	20.03	5.47	3.66		
Total	1,477	1,526	5,519	29,854.00	19.57	5.41	3.62		
Meter Rate Sample†									
Apartment houses	154	395	927	3,580.93	9.09	3.88	2.34	43,542	18,661
Private homes	947	947	3,409	18,076.10	19.01	5.29	3.59	66,150	18,376
Total	1,101	1,342	4,336	21,657.03	16.14	5.00	3.23	59,495	18,414

* Average bill per account, $20.21.
† Average bill per account, $19.69.

used less water. This assumption was borne out by a comparison of the household characteristics of the flat-rate and metered sample groups. A greater percentage of flat-rate households fell into those classifications which rank lower in domestic water demands. This method of analysis was also used to estimate total water use in all flat-rate households, as shown in Table 4. Table 4 is constructed on the assumption that flat-rate households consume water at the same rate as metered households with the same

In spite of somewhat higher estimated household consumption of the meter rate group and the somewhat lower rate the meter group pays as an average on annual bills, the survey group recommended no changes in the relative rate structure between these two groups.

Factors in Water Use

For the purpose of estimating present domestic water consumption among the flat-rate users and for the purpose of projecting domestic water demands

for the future, a survey was made of the various household characteristics and the effects of these characteristics on consumption patterns. The data obtained conforms quite closely to the results of other surveys made previously on a considerably smaller basis (*1*). It is likely, however, that this survey contains the most up-to-date and comprehensive data on this problem, and it is hoped that it will prove useful not only to water departments but also to sanitary engineers for the projection of future demands on the capacity of sewage treatment plants.

An attempt has been made to isolate the effects of three major characteristics on household water consumption: [1] water-using appliances (automatic clotheswashers and dishwashers); [2] the lawn size of the property; and [3] the number of children less than 3 years old in the household. In order to present the results properly it was also necessary to eliminate the effect of household size so that each household size class or frequency could be analyzed separately. The effects of household size on water consumption are presented separately in Table 4. Each of the 898 households making up the sample has been so analyzed that it can fall in one and only one cross-classification. Each of the three major factors under consideration was originally presented so that its effect on water consumption could be studied in isolation. It should be cautioned that in each table presented, although the average water consumption for each subgroup does give some basis of comparison with the next subgroup, it carries some degree of distortion due to the possible weighting of disparate household sizes in each subgroup average. A more valid base for comparison is probably obtained by taking the change in consumption averages for the major frequency classes.

Effect of Appliances

Table 5 gives the effect of automatic, water-using appliances on water consumption. In almost every major classification, and certainly in every comparison involving frequency classes of fifteen or more, water-using appliances indicated increased water consumption. It would appear that each appliance adds about 10,000–20,000 gal to the annual household use.

TABLE 4

Total Estimated Usage of Flat-Rate Users Projected from Stratified Samples

Type of User	Estimated No. of Flat-Rate Households in City	Total Annual Usage *mil/gal*
Minimum lawn		
no appliances	5,157	282.8205
one appliance	2,145	147.7855
two appliances	103	13.1976
Suburban lawn		
no appliances	3,342	194.1809
one appliance	2,176	139.0774
two appliances	303	30.1013
Large lawn		
no appliances	168	9.8890
one appliance	182	14.3274
two appliances	56	4.9314
Totals	13,632	836.3108

Effect of Lawns

For purposes of analysis, each household was classified into three arbitrary categories. Minimum lawns included houses having no lawn or houses with approximately 400 sq ft or less. Suburban lawns are of larger size and usually found in the newer area of the city. The final category, large lawns, belongs to those houses

which occupy more than normal lot sizes. These are houses on country or estate lots. The effects of lawns on water consumption could not be defined precisely by the sample (Table 6). However, if we make comparisons between the frequencies with the larger number of observations, the correlation is generally positive. On the whole it would seem that the suburban lawn increases average annual household water consumption by about 3,000–5,000 gal.

TABLE 5

*Effects of Appliances on Annual Household Usage**

No. of Residents in Household	No Appliances		One Appliance			Two Appliances		
	No. in Sample	Avg Annual Usage *1,000-gal*	No. in Sample	Avg Annual Usage *1,000-gal*	Change in Avg Usage From No Appliances	No. in Sample	Avg Annual Usage *1,000-gal*	Increase in Avg Usage Over One Appliance
Minimum Lawns								
1	10	44.7						
2	39	39.7	13	50.2	+10.5			
3	38	53.6	18	62.5	+8.9			
4	38	58.5	17	55.7	−2.8			
5	18	64.5	10	80.0	+15.5			
6	10	74.6	7	102.3	+24.7			
Suburban Lawns								
1	15	25.8	5	28.6	+2.8			
2	79	45.9	66	53.0	+7.1			
3	56	57.3	70	61.6	+4.3	9	89.8	28.2
4	57	65.0	74	74.3	+9.3	20	93.6	19.3
5	26	64.2	40	82.3	+18.1	8	137.6	55.3
6	6	69.4	15	73.5	+4.1	6	105.7	32.2
Large Lawns								
2	12	58.4	11	60.1	+1.7			
3			9	83.6				
4	7	74.6	17	76.3	+1.7	5	98.6	22.3

* 898 households; only major frequencies are compared in this schedule.

Effect of Children

The original schedules presented data using the cross-classification of households containing children of less than 3 years of age, but the number of households in this group was unfortunately too small to draw any clear-cut conclusions as to children's effect on household water consumption. In general, it would seem that the number of children under three in any given household size may have a very slight negative effect, if any, on household water use. Because the other schedules are much easier to read and analyze if the classification of children under three is eliminated, and because the effect of the age of children on household consumption is negligible, the final, condensed version of the con-

sumption schedules (Table 7) is presented without this classification.

Effect of Household Size

Table 8 demonstrates the effects of household size on water consumption. It would seem quite obvious that water consumption per household goes up as household size increases, but it should be noted that it does so at a decreasing rate—that is, because some considerable part of domestic water use is common or joint, the average use per capita goes down as household size increases. Thus the average annual use per capita in households containing three people is 20,400 gal, but the average annual per capita use in a five-person household is 16,100 gal (*1*).

Rate Structure Study

An essential part of the survey was an analysis of the metered consumption patterns on the rate for the 1-in. and smaller pipe sizes. Not only does this group provide the largest amount of revenue of all metered water users, outside of the steel company, but because the community will eventually be completely metered, the rate schedule and revenue patterns of this group will be extended to the present flat-rate

TABLE 6

*Effects of Lawns and Appliances on Annual Household Usage**

No. of Residents in Household	Minimum Lawns		Suburban Lawns			Large Lawns		
	No. in Sample	Avg Annual Usage *1,000-gal*	No. in Sample	Avg Annual Usage *1,000-gal*	Change in Avg Usage From Minimum Lawns *1,000-gal*	No. in Sample	Avg Annual Usage *1,000-gal*	Increase in Avg Usage Over Suburban Lawns *1,000-gal*
No Appliances								
1	10	44.7	15	25.8	−18.9			
2	39	39.7	79	45.9	+6.2	12	58.4	12.5
3	38	53.2	56	57.3	+4.1			
4	38	58.3	57	64.4	+6.1	7	74.6	10.2
5	18	64.6	26	59.2	−5.4			
6	10	74.6	6	82.7	+8.1			
One Appliance								
2	13	50.2	66	53.0	+2.8	11	60.1	7.1
3	18	62.5	70	61.6	−0.9	9	83.6	22.0
4	17	55.7	74	74.3	+18.6	17	76.2	1.9
5	12	74.2	40	82.3	+8.1	5	117.6	35.3
6	7	102.3	15	73.5	−28.8			
Two Appliances								
3								
4			20	93.6		5	8.6	5.0
5								

* 898 households; only the major frequencies are compared in this schedule.

TABLE 7

Frequency Distribution of Annual Usage, Metered Households

Frequency Class (Annual Usage Range) *1,000-gal*	No. of Billings in Frequency Class in Sample	Portion of Sample in Class *per cent*	Estimated No. of Billings in This Class in City	Total Usage of Class in Sample *1,000-gal*	Portion of Total Usage of Sample *per cent*	Estimated Net Revenue From Class in City *$*	Avg Usage of Class in Sample *gal*	Net Avg Billing* *$*	Difference Between Actual Usage and Minimum†	
									Usage *gal*	Revenue *$*
0– 9	2	0.22	13	18	0.03	221.52	9,000	1.70	−87,000	−15.44
10– 19	20	2.23	132	307	0.53	2,249.28	15,350	2.74	−80,650	−14.30
20– 29	63	7.02	416	1,554	2.68	7,088.64	24,667	4.35	−71,333	−12.69
30– 39	100	11.14	660	3,471	5.98	11,246.40	34,710	6.20	−61,290	−10.84
40– 49	146	16.26	964	6,511	11.21	16,426.56	44,600	7.86	−51,400	−9.18
50– 59	145	16.15	957	7,932	13.65	16,307.28	54,700	9.77	−41,300	−7.27
60– 69	106	11.80	699	6,791	11.69	11,910.96	64,066	11.43	−31,934	−5.61
70– 79	85	9.47	561	6,304	10.86	9,559.44	74,165	13.23	−21,835	−3.81
80– 89	72	8.02	475	6,068	10.44	8,094.00	84,278	15.05	−11,722	−1.99
90– 99	44	4.90	290	4,168	7.17	4,941.60	94,727	16.91	−1,273	−0.13
100–109	28	3.12	185	2,918	5.01	3,441.00	104,214	18.60	8,214	1.56
110–119	28	3.12	185	3,188	5.49	3,761.05	113,857	20.33	17,857	3.29
120–129	17	1.89	112	2,122	3.65	2,495.36	124,823	22.28	28,823	5.24
130–139	14	1.56	92	1,891	3.26	2,217.20	135,071	24.10	39,071	7.06
140–149	10	1.11	66	1,448	2.49	1,706.10	144,800	25.85	48,800	8.81
150–159	4	0.45	27	628	1.08	756.54	157,000	28.02	61,000	10.98
160–169	3	0.33	20	488	0.84	580.60	162,667	29.03	66,667	11.99
170–179	2	0.22	13	353	0.60	409.63	176,500	31.51	80,500	14.47
180–189	2	0.22	13	370	0.64	429.26	185,000	33.02	89,000	15.98
190–199	1	0.11	7	194	0.33	241.43	194,000	34.49	98,000	17.45
200–209	2	0.22	13	409	0.70	463.58	204,500	35.66	108,500	18.62
210–219	2	0.22	13	426	0.73	482.82	218,000	37.14	122,000	20.10
220–229	1	0.11	7	227	0.39	266.98	227,000	38.14	131,000	21.10
230–239	0									
240–249	0									
250–259	0									
260–269	0									
270–279	0									
280–289	1	0.11	7	285	0.49	311.65	285,000	44.55	189,000	27.51
Totals	898		5,927			105,609.08				

* Exclusive of minimum charge.
† Minimum usage for this pipe size, 96,000 gal/yr; minimum rate, $17.04 excluding meter rental.

users. Thus frequency distributions and statistical charts were set up for various classes of users in this group (Tables 7 and 8).

The original frequency distributions showed that both the greatest number of users and the largest amount of revenue collected came from the quarterly billings of both private homes and apartment houses of four units or less.

The present rate structure for the 1-in. pipe size is set at: [1] $0.21 per 1,000 gal for the first 192,000 gal of annual use; [2] a charge of $0.13 per 1,000 gal per year thereafter; and [3] a minimum allowance of 96,000 gal per year, for which a minimum gross bill of $20.04 (or a net bill of $17.04) must be paid.

In analyzing water use patterns among the largest class of water users —that is, small apartments and domestic homes—it soon becomes apparent that the 96,000-gal minimum is too high. More than 82 per cent of the private homes and about 50 per cent of the small apartments do not use 96,000 gal a year, which really means that the average family in Bethlehem pays for more water than it actually uses. Moreover, one of the functions of a metered rate system is to encourage the conservation of water in excess of necessary minimum consumption. Obviously, if the minimum level is set well above the average household use, there is no encouragement to conserve water; rather there is a positive incentive to use water until the minimum is actually reached.

In considering the establishment of a minimum, two other factors come into play. First, the minimum exists to help spread some of the overhead costs of the water plant. Every user connected to the mains represents a potential drain on capacity. The water is available for his use whether he takes a full share or not. Therefore, a minimum charge represents an equitable way to help spread the costs of

TABLE 8

*Annual Usage of Various Household Sizes**

Household Size	No. in Sample	Portion of Sample in Household Size	Avg Annual Usage per Household *1,000-gal*	Avg Usage per Person *1,000-gal*	Total Usage *1,000-gal*	Portion of Total Usage of Sample in Household Size *per cent*
1	34	3.79	33.1	33.1	1,127	1.94
2	228	25.39	49.5	24.7	11,278	19.42
3	207	23.05	61.2	20.4	12,672	21.82
4	235	26.17	70.4	17.6	16,543	28.48
5	115	12.81	80.6	16.1	9,268	15.96
6	49	5.46	88.3	14.4	4,329	7.45
7	21	2.34	99.0	14.1	2,079	3.58
8	2	0.22	81.5	10.2	163	0.28
9	3	0.33	83.3	9.3	250	0.43
10	2	0.22	118.5	11.8	237	0.41
11	0					
12	1	0.11	66.0	5.5	66	0.11
13	1	0.11	59.0	4.5	59	0.10

* Domestic, quarterly metered accounts; sample of 898 households.

TABLE 9

Frequency Distribution of Annual Usage for Apartment Houses of Four or Fewer Apartments, 1-in. Service or Smaller

Frequency Class (Annual Usage Range) *1,000-gal*	No. of Billings in Frequency Class in Sample	Portion of Sample in Class *per cent*	Estimated No. of Billings in This Class in City	Total Usage of Class in Sample *1,000-gal*	Portion of Total Usage of Sample *per cent*	Estimated Net Revenue From Class in City *$*	Avg Usage of Class in Sample *gal*	Net Avg Billing *$*	Difference Between Actual Usage and Minimum*	
									Usage *gal*	Revenue *$*
30– 39	4	2.70	26	140	0.82	443.04	35,000	6.24	−61,000	−10.80
40– 49	8	5.41	53	377	2.22	903.12	47,125	8.46	−48,875	−8.58
50– 59	13	8.78	86	736	4.36	1,465.44	56,615	10.10	−39,385	−6.94
60– 69	18	12.16	119	1,164	6.90	2,027.76	64,667	11.54	−31,333	−5.50
70– 79	17	11.49	112	1,276	7.57	1,908.48	75,059	13.39	−20,941	−3.65
80– 89	8	5.41	53	677	4.01	903.12	84,750	14.93	−11,250	−2.11
90– 99	12	8.11	79	1,137	6.74	1,346.16	94,750	16.91	−1,250	−0.13
100–109	10	6.76	66	1,039	6.16	1,224.30	103,900	18.55	7,900	1.51
110–119	10	6.76	66	1,141	6.77	1,343.76	114,100	20.36	18,100	3.32
120–129	6	4.05	40	753	4.46	896.00	125,500	22.40	29,500	5.36
130–139	9	6.08	59	1,223	7.26	1,430.16	135,744	24.24	39,744	7.20
140–149	4	2.70	26	573	3.39	664.82	143,250	25.57	47,250	8.53
150–159	3	2.03	20	462	2.74	550.00	154,000	27.50	58,000	10.46
160–169	2	1.35	13	329	1.95	381.94	164,500	29.38	68,500	12.34
170–179	4	2.70	26	700	4.15	811.98	175,000	31.23	79,000	14.19
180–189	2	1.35	13	371	2.20	430.43	185,500	33.11	89,500	16.07
190–199	5	3.38	33	974	5.77	1,141.14	194,800	34.58	98,800	17.54
200–209	1	0.68	7	202	1.19	247.66	202,000	35.38	106,000	18.34
210–219	0									
220–229	1	0.68	7	228	1.35	267.82	238,000	38.26	132,000	21.22
230–239	2	1.35	13	473	2.80	509.60	236,500	39.20	140,500	22.16
240–249	1	0.68	7	245	1.46	280.98	245,000	40.14	149,000	23.10
250–259	3	2.03	20	764	4.53	824.20	254,667	41.21	158,667	24.17
290–299	1	0.68	7	296	1.76	320.39	296,000	45.77	200,000	28.73
320–329	1	0.68	7	322	1.91	339.78	322,000	48.54	226,000	31.50
360–369	2	1.35	13	728	4.32	692.64	364,000	53.28	268,000	36.24
520–529	1	0.68	7	524	3.11	496.72	524,000	70.96	428,000	53.92
Totals	148		978			21,851.44				

* Minimum usage for this pipe size, 96,000 gal/yr; minimum rate, $17.04, net of discount and exclusive of meter rent.

TABLE 10

Comparison of Total Billings for Ten Representative Pennsylvania Cities According to Usage, 1957 Rates

City	Min. Annual Usage *gal*	Min. Charge Less Discount *$*	Charge per Year—$										
			12,000 gal	20,000 gal	36,000 gal	50,000 gal	60,000 gal	75,000 gal	96,000 gal	120,000 gal	150,000 gal	200,000 gal	250,000 gal
Bethlehem	96,000	17.04	17.04	17.04	17.04	17.04	17.04	17.04	17.04	21.36	26.76	35.06	40.58
Allentown	20,856	19.35	19.35	19.35	21.73	23.93	25.50	27.86	31.17	34.95	39.67	47.54	55.41
Easton	22,500	12.00	12.00	12.00	19.35	27.77	33.80	42.83	55.47	69.96	88.02	118.12	148.22
Hazleton	16,800	7.44	7.44	9.05	16.20	22.50	27.00	31.60	37.50	45.00	54.00	69.00	84.00
Johnstown													
pump	12,000	20.00	20.00	31.76	52.52	69.88	82.28	100.88	126.92	156.68	193.88	255.88	317.88
gravity	12,000	16.00	16.00	25.20	41.08	54.24	63.64	77.74	97.48	120.24	148.44	195.44	242.44
McKeesport	21,000	9.60	9.60	9.60	15.41	20.06	23.27	28.08	34.82	42.52	52.15	68.20	84.25
New Castle	34,300	15.36	15.36	15.36	16.09	22.35	26.82	33.53	42.81	52.99	65.47	86.20	105.45
Reading	19,500	9.33	9.33	9.45	12.86	15.85	17.99	21.19	25.67	30.79	36.79	46.59	56.39
Pottsville	36,000	31.20	31.20	31.20	31.20	43.45	51.94	65.18	81.33	94.14	110.16	136.86	163.56
Williamsport	20,000	11.20	11.20	11.20	17.28	22.60	26.40	32.10	40.08	46.40	53.60	65.60	75.60

maintaining a plant of a certain capacity for a multitude of users. Second, the minimum level should be set high enough that no household will be inhibited from using an amount sufficient to assure a decent standard of sanitation and health.

After all factors had been considered, it was decided to recommend a minimum for 1-in. pipe sizes of 48,000 gal per year. This should be an adequate minimum consumption for the average Bethlehem household. About 35 per cent of all metered private households presently use no more than this amount, and about 32 per cent of all domestic quarterly accounts (private homes and apartment houses containing less than four households) use 48,000 gal per year or less. It should be pointed out that lowering the minimum will require more attentive and complete meter readings on the part of the route man. It will probably necessitate an expansion in the staff of meter readers.

In setting up a new rate schedule for the 1-in. pipe sizes, the problem was to raise an equitable share of revenue from this group, equal to the percentage to be raised from other classes of users, and at the same time allow for the lowering of the minimum. It was suggested that this could be done by raising the initial rate on water used by a considerable amount and also dropping the quarterly minimum water gallonage from 24,000 to 12,000 gal. This would bring about a substantial increase in total revenue from this group, although many of the smaller users would actually find their annual bills reduced.

As a matter of fact, all those metered consumers presently using less than 54,000 gal per year (about 45 per cent of the private homes) would find their net annual water bills reduced under the suggested rate structure. Moreover, the average private household bill (average consumption around 60,000 gal per year) would show only a nominal rise over the present rates. The comparison charts of other cities showed that the new average annual household bill (at 60,000 gal per year) would still be a good deal less than that of any other Pennsylvania city in the sample (Table 10).

Future Water Use

Using the data and analyses from this survey, a rough forecast may be made of water demands in the future. If, for the next decade or so, a 15 per cent growth in the total number of households is predicted, a 50 per cent increase in the number of households with automatic clothes washers, and perhaps a 500 per cent increase in the present number of automatic dishwashers, and if the trend toward suburban lawns and higher incomes continues, the total annual household water consumption in Bethlehem may well amount to 2.1 bil gal per year by 1970. (This may be compared to the present household consumption of about 1.3 bil gal; the growth forecasted in family household use is thus approximately 60 per cent.) The capacity of the Bethlehem water system, owing to the foresight of the city officials, will be able to meet such an increase in demand.

Reference

1. Studies on Household Sewage Disposal Systems. Federal Security Agency, USPHS, US Govt. Printing Office, Washington, D.C. (1951).

Development and Status of Physical Standards for Plastic Pipe

Raymond J. Faust

A paper presented on Jun. 29, 1959, at the National Congress of Environmental Health (sponsored by the National Sanitation Foundation), Ann Arbor, Mich., by Raymond J. Faust, Secretary, AWWA, New York, N.Y.

BECAUSE of the diligence and foresight of leaders in the plastics industry, many of the industry's problems have been solved, and those that remain are being attacked directly and vigorously Some mistakes were made in the early years of the development of plastic material for the water supply field and the plastics industry was the first to admit it. The objectives of the Society of the Plastics Industry (SPI) and those who chart its course are deserving of great respect.

AWWA Standards

In order to explain the position of AWWA on the issue of the development of standards for plastic pipe, it is necessary to describe briefly the nature and purpose of AWWA standards. AWWA now has 60 standards for various water utility materials and equipment. These standards, developed and revised by committees comprised both of users and of manufacturers, have done much to bring the water supply field to maturity.

AWWA standards are used widely and with a great deal of confidence. They are sound to the point of being, perhaps, a bit conservative, but they insure protection and security to user and manufacturer alike. AWWA feels that the integrity of its standards must be diligently guarded if they are to continue to provide this protection. Thus the Association is hesitant about preparing standards for new materials until those materials have met certain tests. First, AWWA insists that the product or material covered by a standard must be available from more than one firm or outlet—that is, it cannot be a patented item. Second, the item must have a satisfactory record of performance in the field. Normally, 5 years of field experience is considered the minimum. With these principles as guides, AWWA has always been conservative in the development of new standards and has not wished to spend time and energy on the development of standards for items that may not have a future or that have not yet been fully tried and tested.

AWWA and Plastic

For the reasons outlined above, AWWA is not prepared to write standards for plastic pipe and fittings at this time. The Association is actively interested in the application of new materials to the water industry—including plastic materials—and intends to keep abreast of all such new developments. Although AWWA has no plans at present to develop its own standards for plastic pipe and fittings,

it is happy to be represented on the ASA and ASTM committees presently engaged in writing such standards and to keep its members informed on plastic pipe through articles in the JOURNAL.

When information on the materials used in the manufacture of plastic pipe and fittings for water service is more complete and the record of field use has beeen securely established, then AWWA may very well produce its own standards—if the need is apparent.

This description of AWWA's standards policy with regard to plastic pipe may lead some to believe that the Association is deliberately holding back and has no faith in the future of plastics in the field. Nothing could be farther from the truth. Officially, the AWWA Board of Directors has authorized representation on ASA and ASTM committees that are preparing standards for plastic pipe and fittings and has also authorized the establishment of an AWWA committee on plastics. And the Board has maintained a lively interest in these projects.

Early Problems

As far as internal standardization is concerned, the plastics industry, in trying to solve its many problems in the water supply field, was at the outset faced with three vexing problems: [1] establishing that plastics could be used without risk to health, [2] standardizing the dimensions of pipe and fittings, and [3] improving the physical and chemical properties of the several plastics in use.

It was immediately apparent that the public health aspects of the use of plastics for conveying potable water had to be studied and that a "clean bill of health," recorded by a reputable laboratory, had to be given before health authorities would accept the material for use. It was obviously the duty of the plastics industry to establish the proof, and this it did in 1953 by enlisting the aid of the National Sanitation Foundation (NSF). The results of its 2-year study were reported widely and the results have been accepted completely. Few people, if any, have any reservations about the safety of using NSF-labeled plastic pipe for conveying potable water.

The NSF did a good job of dispelling fears in the use of marked plastic pipe for water service. It also standardized test methods for checking the health aspects of the new materials that are constantly being developed by the plastics industry for use in the water supply field.

Commercial Standards

The second standardization job was to determine proper dimensions for plastic pipe—that is, the inside and outside diameters, tolerances, and nomenclature. Many questions arose as to whether the inside or the outside diameter should be the controlling dimension, whether iron-pipe sizes (IPS) or copper tubing sizes (both had previously been standardized) should be followed, or whether a new series of pipe sizes should be developed especially for plastic materials. These questions are not just academic ones for a young industry. Whatever direction the plastics industry took would be expensive, as dies and machinery cost money—a lot of money.

As so often happens in a new field, the most complicated solution possible was attempted. Two series of pipe sizes were manufactured. Some plastic pipe was manufactured in accordance with IPS (covered by ASA

B36.10 Schedules 10, 40, 80, and 120 for polyvinylchloride (PVC) and Schedule 40 for polyethylene) and some other plastic pipe in accordance with solvent-welded pipe (SWP) sizes. The latter are a series of pipe sizes that conform to neither IPS nor copper tubing sizes and that plastic pipe alone would use.

The plastics industry chose to develop commercial standards through the US Department of Commerce, as such standards could be developed in a reasonably short time and would be largely concerned with dimensions.

At present there are six commercial standards available. They represent the needs of the plastics industry. Consumers had little voice in their adoption. These standards cover:

1. Flexible polyethylene pipe
2. Rigid polyvinyl chloride pipe
3. Solvent-welded cellulose acetate–butyrate pipe, in SWP sizes
4. Acrylonitrile butadiene styrene (ABS) Type 1, in IPS sizes
5. ABS Type 1, in SWP sizes
6. ABS Schedule A (thin-walled) pipe.

ASA Standards

The SPI recognized that better standards were needed and chose to develop them through the American Standards Association (ASA). The SPI and ASME sponsored two committees to work on this project. ASA Committee B16, Subcommittee 12, was assigned the job of writing a standard for fittings, and ASA Committee B72 has the responsibility for producing standards for plastic pipe.

On these committees manufacturers and users both have representation so that all interests are served. Standards are being prepared for:

1. Rigid ABS plastic pipe, IPS
2. Rigid unplasticized polyvinyl chloride (UPVC) pipe
3. Polyethylene pipe
4. UPVC, socket-type IPS pipe fittings
5. UPVC, screwed fittings
6. Insert fittings for polyethylene pipe.

All of the proposed standards are presently in their fourth or fifth draft and an effort is being made to push them to completion as soon as possible. The work already represents 3–4 years of effort and 1–2 years more will probably be required before all six standards are adopted as American Standard.

The preparation of these standards is not as simple as it may sound. Each step represents long hours of controversy until a compromise or victory for one side or the other is reached. It must be remembered that these standards are being prepared after the fact—that is, after the manufacturers of plastic pipe and fittings have already been in business for some years producing pipe and fittings to their own dimensions and standards. Thus, when Committee B16 wanted to standardize on sizes for fittings, it was necessary to investigate in detail the sizes of fittings being manufactured by all producers and, from that information, prepare a single set of dimensions for all to follow. To do this required many compromises, so that no one manufacturer would be too seriously harmed.

A job which the users of plastic pipe on ASA Committee B72 performed was the elimination of the SWP sizes from any of the proposed standards. This was done in the interest of true standardization. Omission of the SWP sizes from the proposed stand-

ards does not prevent a manufacturer from continuing to produce SWP pipe, of course, but it will have the same practical effect. It took more than a year to accomplish that apparently simple task. When a manufacturer has $50,000 or more invested in SWP dies, he is not apt to give it up easily.

The SPI, as well as pipe extruders and material suppliers, are presently financing a study of plastic pipe by the Battelle Memorial Institute at Columbus, Ohio. The research program is for the study of the working characteristics and serviceability of extruded thermoplastic pipe. This study is in its fourth year. Its chief objective is to develop and standardize a relatively short-time bursting test that will accurately forecast the service life of the pipe. The work was originally done at a single temperature (73°F) but has since been changed to include higher and lower temperatures. Critical temperatures for plastics, in general, are both higher and lower than room temperatures. At high temperatures plastic has a tendency to lose tensile strength, and at lower temperatures it has a tendency to lose impact strength.

ASTM Standard

ASTM Committee D20 is working on the development of a performance specification for ABS-IPS pipe. This work is well advanced.

Practical Applications

Field experience with plastic materials is limited, but still indicative. For example, to the author's knowledge no presently available cellulose acetate butyrate pipe is considered suited for water service. Of a total of 1,413 butyrate services installed by one company since 1951, 220 have been changed either to another plastic or to metal. The failures were a result of poor joints, brittleness resulting in fractures, rupturing, and failure in flare.

Reports on the use of the other three plastics (PVC, ABS, and polyethylene) are much more favorable. Joints, however, have caused trouble in certain installations and have had to be replaced. Most of these adverse results have been caused by low-impact styrene fittings or corroded clamps. These problems are now mostly corrected. Burying plastic pipe under paved surfaces is still not considered sound practice.

Until adequate standards are available for plastic pipe and fittings, the use of these materials by water utilities should be on an experimental basis.

The plastics industry in the United States has made much progress in attacking and solving its pipe problems. Not all the answers are available at this time, but activity is vigorous and progress is continually being made.

Effects of Synthetic Detergents on Water Supplies

Task Group Report

A report of Task Group 2661 P—Synthetic Detergents: Effects on Water Supplies, presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by Paul D. Haney (Chairman), San. Engr., Black & Veatch, Kansas City, Mo. Other members of the committee are Russell L. Culp, J. Daniel Enright, William D. Hatfield, Harry P. Kramer, H. E. Lordley, James C. Vaughn, and Paul J. Weaver.

IT is estimated that synthetic detergent use will average approximately 20 lb per person during 1959 (*1*). By 1960, average annual use will be on the order of 23 lb per person. Fifteen years ago there was very little use of these synthetic cleansing materials; a 700 per cent increase in the use of synthetic detergents has occurred in the last 10 years. Sales of synthetic detergents (syndets) represent about 72 per cent of the total market for cleansing agents. Although the syndet market is not growing as rapidly now as in the past, the pace may increase as more syndets are used in bar soaps.

The two major constituents of most syndets are a surface-active agent (surfactant) and a builder. The most widely used surface-active agent is alkyl benzene sulfonate, commonly designated ABS. The principal builder compounds are sodium tripolyphosphate and tetrasodium pyrophosphate.

Syndets in Water

Most synthetic detergents sold eventually find their way into sewage and are ultimately discharged into the ground or into surface or ground waters. ABS is not completely removed by sewage treatment although the ABS molecule may be extensively altered. Residual ABS in surface waters was once thought to be the cause of coagulation difficulties at water treatment plants. Although ABS probably does play a role in foaming, it does not appear to cause significant coagulation problems. Extensive laboratory studies (*2, 3*) have shown that detergent-caused coagulation difficulties are more likely due to the presence of the polyphosphate builders than to surface-active agents. A recent investigation of Illinois streams, reported by Engelbrecht and Morgan (*4*), indicated that concentrations of detergent-derived phosphate in the streams studied were very low. Phosphate concentrations were generally much smaller than the concentration (about 0.5 ppm as P_2O_5) that would cause appreciable interference with coagulation. At present, detergent-caused coagulation problems do not appear to be serious.

Concern Over Pollution

Currently there is increasing concern about the pollution of ground water by detergents. A report on de-

tergent pollution of ground water in Suffolk County, N.Y., was published in the December 1958 issue of the JOURNAL (*5*). The study area consisted of a 72-acre residential section having a plot density of 5–6 homes per acre. Water supplies in this area are obtained from individual wells. Sewage disposal is accomplished by cesspools. The authors estimated average detergent use at 2–3 lb per family per week, or 25–40 lb per person per year. Using a figure of 2 lb per family per week, the authors estimated that within the study area approximately 15.6 tons of syndets was discharged annually into the ground water via the cesspools. This corresponds to a detergent loading of about 430 lb/acre per year, or approximately 1.2 lb/acre per day.

Well depths in the study area were 14–56 ft, but the majority of the wells were in the 25–35-ft range. Most of the wells were less than 65 ft from the cesspools. Samples were collected from 186 wells, and detergents components were found in 60 of them. The syndet concentration in terms of the surface-active agent, sodium lauryl sulfate, ranged from 0.1 ppm to more than 1.4 ppm. Analyses were performed by the methylene blue method. This method measures anionic surfactants only. The most common complaints of the water users were bad taste and frothing. Where the syndet surfactant concentration was 1.5 ppm or more, all users complained of bad taste. Frothing complaints started when the concentration reached 1.0 ppm. The origin of the synthetic detergent found in the well water was, of course, sewage, and the presence of detergent in the well water established beyond reasonable doubt that the wells were receiving waste water from cesspools. Thus, syndets gave warning of an offensive and potentially dangerous situation.

Among the authors' conclusions and recommendations were:

1. If wells and cesspools are placed on small lots, it may be anticipated that syndets will sooner or later appear in the well water.
2. Increased well depth and greater distances from cesspools may delay but probably will not prevent syndet contamination of the well water.
3. Syndet surfactants cause frothing and unpleasant tastes at threshold concentrations of 1.0–1.5 ppm.
4. Arrangements should be made to serve the affected areas by public water supplies.

Studies of Pollution

Currently USPHS is studying the problem of ground water contamination. At least a dozen cases of detergent pollution of ground water are known. Sources of pollution include cesspools, septic-tank tile fields, sewage oxidation ponds, streams receiving sewage, holding ponds for industrial wastes, and facilities for waste disposal from commercial laundries.

Many chemicals other than detergents, under certain circumstances, are capable of causing pollution of ground water. Salt water polution has been a serious problem in some of the oil-producing states. Pollutional effects of other chemicals may be even more serious because of acute toxicity. It is emphasized that subsurface pollution, from whatever source, is an insidious destroyer of water resources. The consequences of ground water pollution can be, and generally are, far

more serious than similar pollution of surface waters. Ground waters move slowly and the source of pollution may be quite difficult to locate. Months or years may pass before anyone is aware that ground water pollution is occurring. By the time pollution is detected and corrective measures are undertaken, a large ground water area may be badly damaged, and it may be years before the effects of pollution are eliminated.

Biochemical Degradation

An important aspect of the detergent problem is the apparent resistance of ABS and certain other surface-active agents to biochemical degradation. Although ABS is attacked to some extent by bacteria, apparently the degradation is by no means complete and the end products are still troublesome. An obvious solution, and one that has been repeatedly suggested in the United States and in Britain, would be the use, by detergent manufacturers, of a material less resistant to biochemical action. Soap, which was and still is a widely used cleansing agent, never caused much difficulty because it is readily attacked and destroyed by bacteria. This, unfortunately, is not true of the currently used synthetics. A change to a less resistant substitute would not be easy, however, for ABS is produced on a large scale. Production of this complete organic chemical in 1956 was 455,444,000 lb (*6*). Detergent manufacturers, however, can bring a great deal of scientific talent and practical knowledge to bear on this problem and are making a serious attempt to develop alternative surface-active agents that will perform at least as well as ABS and be susceptible to biochemical degradation.

The chemical structure of ABS appears to be the key to its biochemical behavior. McKinney and Symons (*7*) have recently reported research that throws considerable light on the subject of the bacterial degradation of ABS. These investigators concluded that ABS cannot be completely degraded by sewage treatment processes and that failure to degrade completely is caused by a quaternary carbon atom in the alkyl group, located where the hydrocarbon chain joins the benzene ring. This quaternary carbon apparently blocks bacterial metabolism. This conclusion seems to be supported by the findings of the British technical committee on synthetic detergents (*8*). The committee reported recently that a new type of ABS has been developed which is susceptible to biochemical degradation. The new ABS apparently differs from the ABS in current use only with respect to chemical structure and is entirely satisfactory for use in detergent manufacture. The new ABS is not available in large quantities, but enough of it was furnished to the committee to permit laboratory and pilot plant tests of its behavior during sewage treatment. The results of these tests showed rather conclusively that the new material was much more easily degraded. Whereas trickling filters removed only about 67 per cent of conventional ABS, they removed 94 per cent of the new ABS. Some preliminary measurements of foam formation indicated that the new material had much less tendency to cause effluent foaming. In fact, when the new material was employed, effluent foam was but little more than that encountered in a similar effluent containing no ABS of any kind.

This task group will attempt to keep in touch with future developments and

will report them to the Association periodically.

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Ferric Sulfate Coagulation in the Presence of Synthetic Detergents

Jesse M. Cohen, George A. Rourke, and Richard L. Woodward

A contribution to the Journal by Jesse M. Cohen, Chemist; George A. Rourke, Chemist; and Richard L. Woodward, Chief, Water Supply, all of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

DURING the past few years there have been numerous published reports of water treatment difficulties that have been ascribed to the presence of synthetic detergents (*1–5*). These difficulties include, among others, interference with coagulation, rising floc, inability to remove turbidity, taste and odor production, and dramatic foaming.

Howells and Sawyer (*6*) found that interference with color removal by alum coagulation does not occur with various anionic and nonionic surface-active agents (surfactants) in concentrations of 10 ppm or less. Smith, Cohen, and Walton (*7*) found that the surfactant component of synthetic detergents does not interfere with alum coagulation at concentrations of up to 20 ppm. Serious interference does occur, however, when as little as 1 ppm of polyphosphate is present. This interference can be overcome by increasing the alum dose, the amount necessary varying linearly with the concentration of polyphosphate. Howells and Sawyer (*6*) are in general agreement with these findings and with the use of color removal rather than turbidity as a measure of coagulation efficiency.

This investigation is an extension of a previous work (*7*) to include the effects of synthetic-detergent components on coagulation with ferric sulfate and includes a detailed study of the removal of surfactants.

Nature of Experiments

The test water used in most of the experimental work was a synthetic turbid water whose preparation has been described in a previous work (*7*), and the surfactants studied were the same purified materials used in that work. In addition, commercial sodium tripolyphosphate was recrystallized several times before use. Although the decahydrate of sodium tripolyphosphate was used, concentrations are expressed in terms of the anhydrous form.

Reagent grade ferric sulfate corresponding to the chemical formula $Fe_2(SO_4)_3 \cdot 9H_2O$ was used in all of the coagulation experiments. Results are expressed in terms of that compound.

Coagulation tests were performed with a six-place mechanical stirring apparatus using 2-liter portions of test water in 1-gal, square-sided jars.

In the previous work, and in that described in much of the literature, the quality of a coagulation was evaluated merely by visual observation of the floc and measurement of residual turbidity. Such evaluation is neither accurate nor

objective and is so subject to personal judgment that duplication of data among laboratory investigators is difficult to obtain. To circumvent this difficulty, a settling-rate determination was used throughout this study. This method has also been described in a previous publication (*8*).

Electrometric alkalinity and pH determinations were made routinely on all raw-water preparations and on some finished-water samples. The data served merely to insure that reproducible conditions of test water had been maintained. Determinations for iron were done colorimetrically on water samples immediately following addition of ferric sulfate and on settled, coagulated water. To reduce interference by polyphosphate, *2–2′–2″* tripyridine was used as reagent.

Two methods were used to determine the concentrations of the surfactant added to the jars and of the re-

TABLE 1

Coagulation Tests on Surfactants in Soft Synthetic Turbid Water

Item	Surfactant Concentration—*ppm*						Surfactant Interference Concentration*—*ppm*
	0	2	4	8	16	32	
ABS-1							
First floc—*min*	8	8	8	8	8	12	16—32
Floc quality	good	good	good	good	good	fine	
Effluent turbidity—*units*	4	3	3	4	4	9	
ABS-2							
First floc—*min*	6	6	6	7	11	—	8—16
Floc quality	good	good	good	good	fine	none	
Effluent turbidity—*units*	3	4	4	5	12	83	
ABS-3							
First floc—*min*	6	6	6	6	6	20	16—32
Floc quality	good	good	good	good	good	poor	
Effluent turbidity—*units*	3	2	3	2	3	23	
ABS-4							
First floc—*min*	6	7	7	8	28	—	8—16
Floc quality	good	good	good	good	good	none	
Effluent turbidity—*units*	4	4	5	8	38	101	
Lauryl Sulfate							
First floc—*min*	7	6	8	9	—	—	4—8
Floc quality	good	good	good	good	none	none	
Effluent turbidity—*units*	5	5	9	14	105	106	

* Where a range is shown, the interference concentration lies between the two values.

sidual surfactant following coagulation. Analyses for surfactant in the early part of the study were made by the methyl green procedure (*9*). It was soon found that analyses could be made as precisely and more rapidly by using a two-phase titration procedure proposed by Hoyt and Walter (*10*). The cetyltrimethylammonium bromide (CETAB) solution used for the titration was standardized against potassium dichromate. All calculations were based on a surfactant with a molecular weight of 348, the weight of a sodium dodecylbenzenesulfonate, and results are expressed in terms of the latter compound.

Analyses for orthophosphate and soluble polyphosphate were determined by the colorimetric molybdenum blue method. Stannous chloride was used as reducing agent and color intensity was measured with a spectrophotometer (*11*).

The study was divided into determinations of four things:

1. The effects of various surfactants on ferric sulfate coagulation
2. The effects of a single surfactant under several conditions of coagulation
3. The effectiveness of ferric sulfate coagulation in removing surfactant from solution
4. The influence of sodium tripolyphosphate on ferric sulfate coagulation.

Various Surfactants

Four purified sodium dodecylbenzene sulfonates, designated ABS 1–4, and sodium lauryl sulfate were tested for their effect on ferric sulfate coagulation. These surfactant materials were added in increasing concentrations of 2–32 ppm to a series of six jars containing synthetic turbid water. Ferric sulfate solution was added to a concentration of 8 ppm as the coagulant. At the end of 30 min of flocculation, the treated waters were allowed to stand for an additional 30 min before samples were withdrawn for turbidity measurements. The results, shown in Table 1, indicate that with minimum doses of ferric sulfate, 4–32 ppm of surfactant were required before interference became apparent. These concentrations of surfactant are many times greater than any that are likely to be found in a public water supply. To show the effect of variable experimental conditions on coagulation, one of the alkyl benzene sulfonates, ABS-1, was studied in detail.

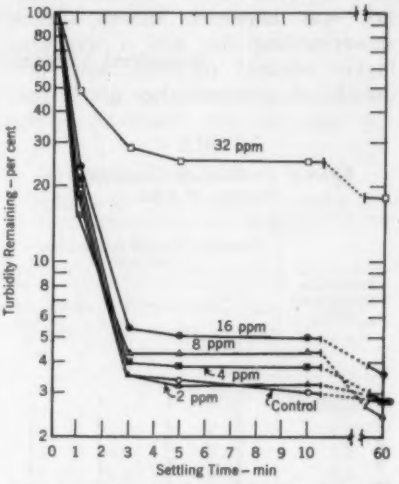

Fig. 1. Effect of Various Concentrations of ABS-1 on Coagulation in Synthetic Turbid Water

The characteristics of the water used were as follows: pH, 7.6; alkalinity, 40 ppm; hardness, 0; turbidity, 110 units; coagulant (ferric sulfate) 10 ppm; temperature, 22°C.

ABS-1 Concentration

In these experiments, ABS-1 was added to synthetic turbid water in concentrations of 0–32 ppm. Coagulation

was accomplished by adding 10 ppm of ferric sulfate (Fig. 1). The settling-rate curves show a slight decrease in the quality of the ferric sulfate floc as surfactant concentration is increased. The lowered settling rate is apparent only during the first 10 min of sedimentation. The quality of the effluents produced in the presence of 8 ppm or less of ABS-1 was essentially uniform. With 16 ppm the quality of coagulation was impaired, and a slightly slower-settling floc and a somewhat higher residual turbidity were produced. A concentration of 32 ppm ABS-1 was clearly detrimental to the coagulation.

TABLE 2

Effect of Turbidity on Coagulation in Presence of ABS-1

Surfactant Concentration *ppm*	Turbidity After 60-min Settling—*per cent*			
	Initial Turbidity—*units*			
	25	110		330
0 (Control)	3	4	4	1
2	5	3	3	3
4	5	3	3	1
8	4	3	3	2
16	5	4	5	4
32	21	19	19	21

Turbidity

Because turbidity could be a factor in the coagulation of water containing surfactant, samples containing three different concentrations of turbidity—25, 110, and 330 units—were coagulated with 10 ppm of ferric sulfate in the presence of ABS-1 concentrations of 0–32 ppm. From Table 2 it is clear that neither turbidity nor surfactant concentrations of 16 ppm or less have any significant influence on the clarity of the effluent obtained with ferric sulfate coagulation. With 32 ppm of surfactant, the effluent contains increased amounts of residual turbidity.

Calcium Ion

Although it was not anticipated that calcium would have any effect on coagulation in the presence of surfactant, it was desirable to check several concentrations. Calcium ions, in the form of calcium chloride, were added to synthetic turbid water. The data obtained in these experiments showed that calcium in concentrations 0–300 ppm (as $CaCO_3$) had no effect on ferric sulfate coagulation in the presence of surfactant concentrations of 32 ppm or less. It was found, as others have observed, that calcium ions improve coagulation, and, in this instance, tolerance for surfactant was increased to concentrations greater than 32 ppm, the latter concentration yielding a coagulation fully as satisfactory as the lower concentrations.

TABLE 3

*Removal of ABS-1 by Coagulation With Increasing Amounts of Ferric Sulfate**

Ferric Sulfate *ppm*	Final pH	ABS-1 Concentration After Coagulation *ppm*	ABS-1 Removed *per cent*
10	7.6	9.41	1.2
20	7.4	8.91	6.4
30	7.2	8.98	5.7
40	7.15	9.01	5.4
50	7.0	8.96	5.9
60	6.9	9.05	4.9

* Synthetic turbid water contained 50 ppm alkalinity, 100 units turbidity, and 9.52 ppm ABS-1.

Surfactant Removal

Evidence in the literature (*12, 13*) has amply demonstrated that alum coagulation is ineffectual in removing surfactants from water. In a plant-scale trial in which 300,000 gpd was

treated, Hammerton (*12*) found that no reduction in surfactant concentration was obtained during a 16-day period. The average of 16 daily determinations of surfactant in the raw water showed 1.56 ppm, as compared to 1.57 ppm found in the clarified water. Some factors which may affect the removal of surfactants by ferric sulfate coagulation were studied in this investigation.

Increased Ferric Sulfate

Increasing concentrations of ferric sulfate of 0–60 ppm were used to coagulate synthetic turbid water containing the added surfactant material, ABS-1. Surfactant concentrations were determined before and after coagulation; the results are shown in Table 3. Except for a surfactant removal of 1.2 per cent with the minimum amount of ferric sulfate, removals with increasing amounts of coagulant amounted to 4.9–6.4 per cent. No correlation was observed between the removal of the surfactant and the coagulant dose. For practical purposes one can conclude that ferric sulfate coagulation does not remove this surfactant.

pH

Influence of pH on the removal of ABS-1 by ferric sulfate coagulation was determined by coagulating synthetic turbid water containing 9.52 ppm of ABS-1 with 10 ppm of ferric sulfate after pH adjustment with dilute sulfuric acid. The data obtained (Table 4) show that the percentage of surfactant removed was insignificant within the pH range of 4.7–7.6.

Surfactant Concentration

To check the influence of surfactant concentration on surfactant removal by ferric sulfate, tests were made in which conditions of pH, alkalinity, turbidity, and coagulant dose were held constant while varying amounts of surfactant were added. Results of three experiments (Table 5) show that only small amounts of the surfactant are removed by ferric sulfate coagulation. The initial concentration of the surfactant had no effect on the percentage removed. The average amount of surfactant removed in all the tests was 5.7 per cent.

Turbidity Increases

Increasing amounts of clay turbidity slightly increased the removal of ABS-1 by coagulation with ferric sulfate (Table 6). With turbidities ranging up to 170 units, an average removal of 3.4 per cent was obtained. With higher turbidity values, 325–2,750 units, the average removal of surfactant increased to 12.4 per cent.

TABLE 4

*Influence of pH on Removal of ABS-1 by Coagulation with 10 mg/l Ferric Sulfate**

Ferric Sulfate *ppm*	Final pH	ABS-1 Concentration After Coagulation *ppm*	ABS-1 Removed *per cent*
10	4.7	8.98	5.8
10	5.4	8.98	5.8
10	6.2	9.08	4.8
10	6.8	9.26	3.0
10	7.2	9.25	3.0
10	7.6	9.53	1.0

* Synthetic turbid water contained 50 ppm alkalinity, 100 units turbidity, and 9.52 ppm ABS-1.

Activated Carbon

Reduction of ABS-1 to very low residuals was obtained with activated carbon, but the dosages required were high. In these tests, solutions of 2.0 ppm of ABS-1 were treated with increasing amounts of activated carbon

TABLE 5

Effect of Surfactant Concentration on Its Removal by Coagulation With Ferric Sulfate

Conditions	Surfactant Concentration—*ppm*		Removal* *per cent*	Avg Removal *per cent*
	Before Coagulation	After Coagulation		
Turbidity, 82 units;	2.13	2.09	1.9	
alkalinity, 51 ppm; pH 7.5;	4.03	3.69	8.4	
ferric sulfate, 10 ppm	7.80	7.22	7.4	
	15.6	15.0	3.8	
	31.1	30.6	1.6	4.6
Turbidity, 100 units;	1.82	1.63	10.4	
alkalinity, 50 ppm; pH 7.6;	3.96	3.84	3.0	
ferric sulfate, 10 ppm	7.03	7.26	+3.3	
	16.9	17.3	+2.4	
	32.7	30.8	5.8	4.8
Turbidity, 106 units;	2.00	2.10	+5.0	
alkalinity, 40 ppm; pH 7.4;	3.90	3.60	7.7	
ferric sulfate, 10 ppm	7.90	7.40	6.3	
	15.7	14.8	5.7	
	31.5	29.2	7.3	6.8

* Plus values were not included in the calculations for average removal.

TABLE 6

Influence of Turbidity on Removal of ABS-1 by Coagulation With Ferric Sulfate

pH	Alkalinity *ppm*	Turbidity *relative units*	Ferric Sulfate *ppm*	Surfactant Concentration—*ppm*		Removal *per cent*	Avg Removal *per cent*
				Before Coagulation	After Coagulation		
7.5	48	26	10	2.0	2.04	+2.0	
				4.08	4.04	1.0	
				7.92	7.73	2.4	
				15.6	15.3	1.9	
				30.8	30.2	1.9	1.8
7.4	45	100	10	4.03	3.98	1.2	
				15.4	15.7	+2.0	
				4.17	3.98	4.6	
"				15.5	15.5	0	1.9
7.35	48	325	10	4.56	3.97	12.9	
				17.7	15.1	14.7	13.8
7.45	48	450	10	5.01	4.21	16.0	
				18.4	14.5	21.2	18.6
7.3	100	2	50	10.0	9.6	4.0	
		170		10.0	9.5	5.0	
		330		10.0	9.2	8.0	
		680		10.0	9.0	10.0	
		1380		10.0	8.9	11.0	
		2750		10.0	8.7	13.0	8.5

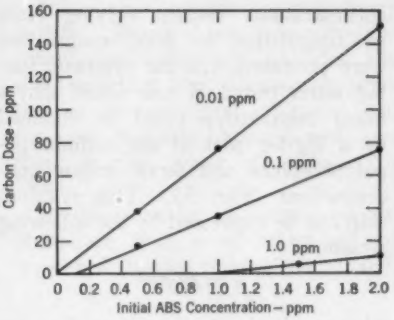

Fig. 2. Carbon Dosage Chart for ABS Removal

The concentrations shown with each line represent desired residuals.

and were stirred for 1 hr. Carbon was removed by filtration through a sintered glass funnel, and surfactant residuals were determined. The data were plotted according to the Freundlich equation (*14*) and the constants of the resulting curve were used to construct the carbon dosage curves in Fig. 2. These curves show that 154 ppm of carbon is required to reduce 2.0 ppm of ABS to a residual of 0.01 ppm; that 76 ppm of carbon is necessary for a residual of 0.1 ppm; and that 10.5 ppm of carbon is required if the desired residual is 1.0 ppm.

These results are in fairly good agreement with those reported by Filicky (*15*) but show poorer removal by carbon than that obtained by Vaughn (*13*).

Sodium Tripolyphosphate

Reports (*6, 7*) have stated that concentrations as low as 1–2 mg/l of sodium tripolyphosphate have prevented alum coagulation of soft, synthetic turbid water and soft, natural colored waters. To determine the concentration at which sodium tripolyphosphate interferes with ferric sulfate, soft, synthetic turbid water was used as the test medium. Solutions containing increasing concentrations of sodium tripolyphosphate ranging from 0.025 to 0.4 ppm were coagulated with 10 ppm of ferric sulfate. Settling-rate curves (Fig. 3) show that concentrations of sodium tripolyphosphate as low as 0.025 ppm decrease the settling quality of the ferric sulfate floc. This slight interference in the lower concentrations becomes significant at a tripolyphosphate concentration of 0.1 ppm. With 0.4 ppm of tripolyphosphate, no coagulation could be obtained. With this test water, ferric sulfate is about ten times as sensitive to interference by sodium tripolyphosphate as is alum.

Removal of Interference

As with alum coagulation, interference with ferric sulfate coagulation by sodium tripolyphosphate can be over-

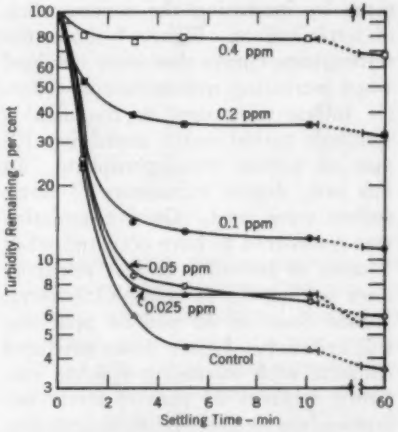

Fig. 3. Effect of Various Concentrations of Sodium Tripolyphosphate on Coagulation in Synthetic Turbid Water

Water characteristics were: pH, 7.8; turbidity, 116 units; alkalinity, 52 ppm; coagulant (ferric sulfate), 10 ppm.

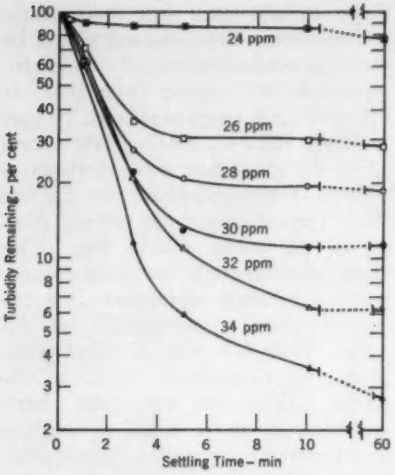

Fig. 4. Effect of Various Concentrations of Ferric Sulfate on Coagulation in the Presence of Sodium Tripolyphosphate

The tripolyphosphate concentration was 0.8 ppm.

come by increasing the concentration of ferric sulfate. Figure 4 shows the settling-rate curves that were obtained when increasing concentrations of ferric sulfate were used to coagulate a synthetic turbid water containing 0.8 ppm of sodium tripolyphosphate. In this test, 2-ppm increments of ferric sulfate were used. Good coagulation was considered to have occurred when 5 units of turbidity or less remained after settling for 60 min. Only ferric sulfate doses of 32 and 34 ppm met this criterion. Lesser doses produced effluents with increasing residual turbidity, whereas 24 ppm of ferric sulfate was unable to effect any coagulation.

The set of curves in Fig. 4 is typical of the results obtained when sufficient ferric sulfate was added to overcome tripolyphosphate interference, where within a 10-ppm range of ferric sulfate concentrations results varying from no coagulation to good coagulation were produced. In the synthetic turbid water tested, it was found that a linear relationship could be obtained by a log-log plot of the sodium tripolyphosphate and ferric sulfate concentrations (Fig. 5). This relationship can be expressed by the following equation:

$$x = 38y^{0.88}$$

where x is the ferric sulfate dose required and y is the concentration of sodium tripolyphosphate. That this relationship is valid in at least one practical example will be shown later.

Residual Iron

The presence of a surfactant in water does not affect the residual iron in

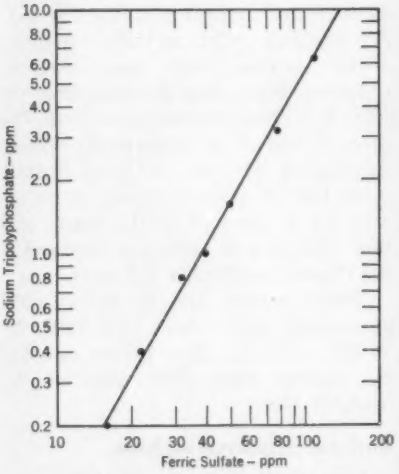

Fig. 5. Relationship Between Tripolyphosphate Concentration and Ferric Sulfate Necessary for Good Coagulation

The equation of the line is $x = 38y^{0.88}$. *The tripolyphosphate and ferric sulfate are expressed as* $Na_5P_3O_{10}$ *and* $Fe_2(SO_4)_3 \cdot 9H_2O$, *respectively.*

solution after coagulation with ferric sulfate. Residual-iron concentrations remain uniformly low provided that the surfactant concentration is below the interference level. Typical data for iron residuals obtained with synthetic turbid water are shown in Table 7.

In the presence of sodium tripolyphosphate, iron is so effectively sequestered that no residual metal could be detected by the analytical procedure after coagulation.

TABLE 7

Removal of Iron by Coagulation in Presence of Surfactants

Surfactant Concentration *ppm*	Ferric Sulfate Added *ppm*	Quality of Coagulation	Ferric Sulfate Remaining *ppm*	Removal *per cent*
		ABS-1		
0	2.00	good	.04	98.0
2	2.00	good	.06	97.0
4	2.00	good	.08	96.0
8	2.00	good	.04	98.0
16	2.00	good	.04	98.0
32	2.00	poor	.10	95.0
		Lauryl Sulfate		
0	1.59	good	.013	99.2
2	1.59	good	.013	99.2
4	1.59	good	.013	99.2
8	1.59	good	.023	98.6
16	1.59	poor	0.69	56.6
32	1.59	poor	1.4	11.9

Wash Water Experiments

At the conclusion of the study, the work on laboratory prepared water was checked with a study on a waste wash water. For this purpose, a commercial synthetic-detergent formulation was used to wash ordinary household laundry in a home washing machine. The wash water was analyzed for surfactant and sodium tripolyphosphate content. Analysis for surfactant by the two-phase titration method showed 938 ppm surfactant, assuming a molecular weight of 348, which was equivalent to a concentration in the wash water of 0.52 per cent commercial synthetic-detergent formulation containing 18 per cent surfactant. Analysis for sodium tripolyphosphate showed 2,800 ppm in the wash water, indicating that the commercial synthetic detergent contained 54 per cent sodium tripolyphosphate. During the washing period only 2.4 per cent of the sodium tripolyphosphate was hydrolyzed to orthophosphate to produce 52 ppm orthophoshate as PO_4^{--} in the discharged wash water.

Increasing amounts of the wash water were then added to synthetic turbid water to yield solutions containing known amounts of sodium tripoly-

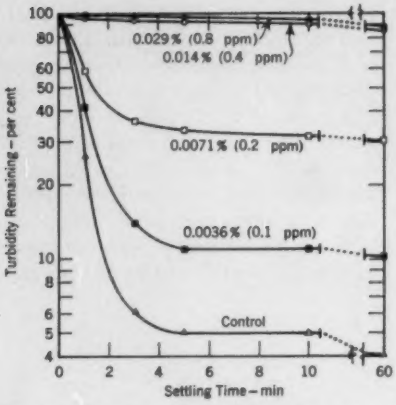

Fig. 6. Effect of Various Concentrations of Laundry Wash Water on Coagulation With Ferric Sulfate

The ferric sulfate concentration was 10 ppm. Data in parentheses are concentrations of sodium tripolyphosphate.

phosphate. Coagulation of these solutions was attempted with 10 ppm ferric sulfate, with the results shown in Fig. 6. Impaired coagulation, as evidenced by a lower settling rate and higher residual turbidities, occurs when only 0.0036 per cent of wash water is present—which is equivalent to 0.1 ppm tripolyphosphate. No coagulation occurs when 0.014 per cent or more wash water is present.

As shown in Fig. 5, interference of sodium tripolyphosphate in ferric sulfate coagulation may be overcome by increasing the coagulant dose in accordance with the derived equation of the line. The following experiment showed that this equation is also applicable to test waters containing sodium tripolyphosphate contributed by laundry wash water.

For this test, laundry wash water was added to synthetic turbid water to make a 0.014 per cent solution. The resulting test solution contained 0.40 ppm sodium tripolyphosphate. Portions of this solution were then treated with increasing amounts of ferric sulfate ranging from 11 to 26 ppm in 3-ppm increments. The results show (Fig. 7) that at least 23 ppm ferric sulfate was required to produce an effluent containing 5 per cent of residual turbidity or less. This is the same value that would be predicted from Fig. 4.

Having determined that 23 ppm ferric sulfate was required to coagulate a solution containing 0.014 per cent laundry wash water, another series of coagulations was made in which increasing amounts of ferric sulfate were added, above the required minimum, to determine whether surfactant material was removed. The data obtained (Table 8) indicate that coagulation

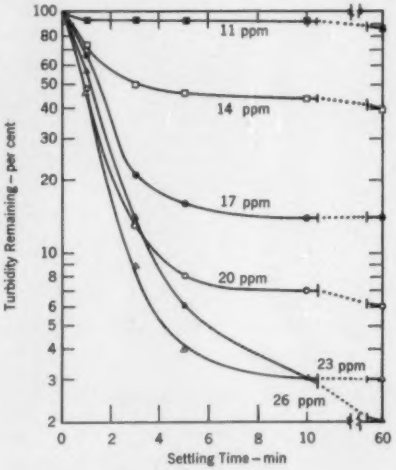

Fig. 7. Effect of Various Concentrations of Ferric Sulfate in Presence of Laundry Wash Water

Laundry wash water concentration was 0.014 per cent (0.4 ppm sodium tripolyphosphate).

with ferric sulfate removes only insignificant amounts of surfactant material. The lowest dose of ferric sulfate, 20 ppm, did not produce an adequate coagulation, which confirms the minimum dose previously determined as 23 ppm.

Discussion

Between 1950 and 1954 a number of reported instances of coagulation difficulty attributed to synthetic detergents occurred at water plants. These are well summarized in an AWWA Task Group Report (*2*). No reports of recurrence of such difficulties have been noted since that time in spite of the steadily increasing use of synthetic detergents.

The studies of Smith, Cohen, and Walton (*7*), Howells and Sawyer (*6*), and the author's of this report have shown that in controlled laboratory tests the surfactants used in household synthetic detergents do not interfere with coagulation at concentrations of less than 16 ppm.

The surfactant content of municipal sewage averages 5–10 ppm. Sewage treatment and natural purification processes reduce this by varying amounts. At Chanute, Kan. (*16*), when waste water was being recycled, the ABS concentration averaged 13.6 ppm in untreated sewage, 10.4 ppm in treated sewage, 4.6 ppm in raw water, and 4.4 ppm in treated water during the period of worst water quality. Relatively little information is available on ABS concentrations in streams in the United States. Rivers in Great Britain have shown concentrations of 0.2–4.9 ppm (*17*). The authors know of no streams in the United States in which concentrations as high as 5.0 ppm have been found. Some of the earlier reports of higher concentrations are doubtful because packaged detergents were used as a standard; such detergents commonly contain as little as 18 per cent surfactant.

Thus, it is doubtful that water supplies have been or are likely to be contaminated by ABS to levels high enough to cause interference with coagulation. The laboratory studies referred to above have shown that complex phosphates of the type used in household detergents are capable of causing interference with coagulation. There are several reasons for questioning the importance of these complex phosphates in water treatment, however. First, their interference may be eliminated by increased coagulant dosage. Second, hardness tends to reduce or eliminate their interference. Third, they are rapidly hydrolyzed (*18*) in sewage to relatively innocuous orthophosphates. Very little information is available on the concentration of complex phosphates in streams receiving sewage. Dietz' (*19*) studies showed that total phosphate concentrations (as P_2O_5) in the range of 1 ppm or less would be typical for Illinois waters. Most of this sampling, however, was done on streams and

TABLE 8

*Removal of Surfactant From Diluted Laundry Wash Water**

Jar No.	Ferric Sulfate *ppm*	Final pH	Final Turbidity *units*	Residual Surfactant *ppm*
1	20	7.15	54	
2	30	7.05	4	0.11
3	40	6.95	3	0.11
4	50	6.80	2	0.12
5	60	6.75	2	0.12
6	70	6.70	2	0.11

* Water analysis: pH, 7.4; turbidity, 102 units; alkalinity, 50 ppm; sodium tripolyphosphate, 0.4 ppm; surfactant, 0.13 ppm.

lakes receiving no sewage pollution. Dietz further showed that, in streams receiving sewage effluents, total phosphate concentrations increased to 3.4 ppm (as P_2O_5) with complex phosphates comprising 15 per cent of the total.

The results at Chanute (*16*) are again of interest. During the period of worst water quality, the concentration of complex phosphates in the untreated sewage averaged 19 ppm. It was reduced to 7 ppm in the treated sewage and to 1 ppm in the raw water. Treatment in the plant reduced it further to 0.5 ppm. This illustrates the relatively large and rapid reduction in complex phosphate concentrations that occurs in sewage treatment and by natural purification processes such as were active at Chanute. It is also pertinent that no interference with coagulation comparable to that reported elsewhere (*5, 20, 21*) was noted at Chanute.

From this evidence it seems likely that the interference with coagulation attributed to detergents probably had some other cause or causes, and although detergents were undoubtedly present and almost certainly were responsible for foaming and possibly contributed to other difficulties, it seems probable that the coagulation difficulties were due to the presence of other contaminants in addition to synthetic detergents.

Summary

Components of household synthetic detergents were investigated for their effects on ferric sulfate coagulation, under laboratory conditions, with laboratory-prepared turbid water. Confirmatory data were also obtained using laundry wash water as a source of synthetic detergent.

Five anionic surfactant materials produced no discernible decrease in the quality of ferric sulfate coagulation until concentrations of 8–32 ppm were present. Higher concentrations interfered by producing a slow-settling floc and high residual turbidities. Neither turbidity nor surfactant concentrations up to 16 ppm had any significant influence on the clarity of the effluent obtained with ferric sulfate coagulation. With 32 ppm of surfactant, effluent quality suffered an increase in residual turbidity.

In the presence of calcium-ion concentrations up to 300 ppm (as $CaCO_3$), even greater amounts of surfactant could be tolerated in the coagulation. As much as 32 ppm of ABS-1 had no detrimental effect, whereas this concentration consistently interfered with coagulation when no calcium ions were present.

Coagulation with ferric sulfate is ineffective in removing surfactants from water. Doses of ferric sulfate six times the minimum required for coagulation remove only 5–6 per cent of the surfactant present. Adjustment of pH to as low as 4.7 did not materially aid in the removal of surfactant compounds. The low removals were independent of the original concentration of the surfactant. Increased removals, averaging 13 per cent, were obtained with turbidities of 450–2,750 units.

Activated carbon removed surfactants from solution, but high dosages were required. To reduce 2.0 ppm ABS to a residual of 0.01 ppm, required 154 ppm carbon.

In the test water, a very small amount of sodium tripolyphosphate, 0.1 ppm, adversely affected the quality of coagulation. As little as 0.4 ppm completely prevented coagulation with minimum doses of the coagulant.

Interference from sodium tripolyphosphate was overcome by increased doses of ferric sulfate. The relationship between the concentration of sodium tripolyphosphate and the amount of ferric sulfate required to overcome interference is linear on a log-log plot. An equation expressing this function was developed.

With concentrations of surfactant below the interference level, substantially complete removal of iron was obtained.

Work with laundry wash water in synthetic turbid water in concentrations which might be expected under practical conditions confirmed the laboratory findings with pure compounds.

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Use of Chlorine and Its Derivatives in Taste and Odor Removal

D. W. Ryckman and S. G. Grigoropoulos

A paper presented on Apr. 8, 1959, at the Conference on Design Criteria and Control of Taste and Odor in Water Supplies (cosponsored by the Missouri Section, AWWA), at the Univ. of Missouri, Columbia, Mo., by D. W. Ryckman, Dir., San. Eng. Research & Graduate Program, and S. G. Grigoropoulos, Research Instructor of San. Eng., both of Washington Univ., St. Louis, Mo.

CHLORINATION has been practiced in the water supply industry for approximately 50 years. During this period much progress has been made in chlorination practices. The purpose of chlorine application has been twofold—that is, for disinfection and for control of tastes and odors. Although most of the recognized problems of disinfection have been solved, much work remains to be done in the field of tastes and odors. The importance of controlling tastes and odors in public water supplies is reflected in the increase in the number of water plants practicing some form of taste and odor control (Fig. 1).

The purpose of this article is to review the different methods of using chlorine and its derivatives to combat tastes and odors and to present a short review of pertinent investigations now in progress at the sanitary engineering laboratories of Washington University, St. Louis.

Chlorination Practices

A number of processes have been employed to remove taste and odor with chlorine and its derivatives. In chronological order these processes include: chlorine-ammonia treatment, superchlorination, free residual chlorination, superchlorination and dechlorination, and chlorine–chlorine dioxide treatment.

Chlorination practices may be divided into four major groups. A review of these groups is given below. An effort has been made to use the terminology which has been accepted by AWWA.

1. *Combined residual chlorination (chlorine-ammonia treatment).* This process is the application of chlorine to water to produce with ammonia a combined available chlorine residual. It is a common practice to maintain this residual through part or all of the water treatment plant or distribution system. Combined chlorine residuals are chloramines and other chlorine derivatives which are products of chlorine and ammonia or amines, and may be measured by the standard orthotolidine arsenite test. Such practices as simple chlorination, marginal chlorination, and chlorine-ammonia treatment may be included in this group.

2. *Free residual chlorination (breakpoint process).* This process is the application of chlorine to water to produce, directly or through the destruction of ammonia or nitrogenous

organic material, a free available chlorine residual. This residual is maintained through part or all of the water treatment plant or distribution system. Free chlorine residuals include elemental chlorine, hypochlorous acid ($HOCl$), and the hypochlorite ion (OCl^-), and may be measured by the standard orthotolidine arsenite test.

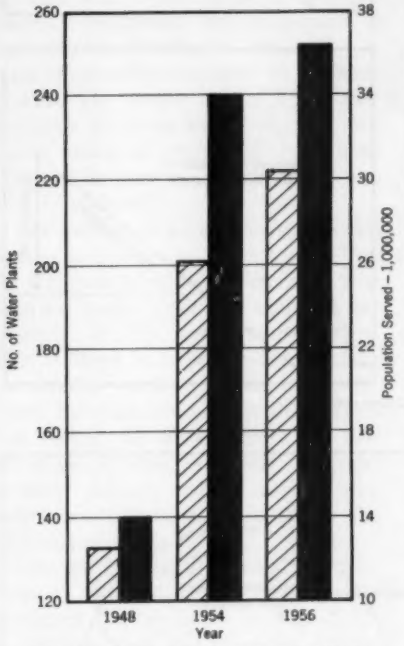

Fig. 1. Increases in the Practice of Taste and Odor Control

Cross-hatched bars represent numbers of plants; black bars represent populations served.

3. *Superchlorination and dechlorination.* Superchlorination, as originally practiced, was defined as the application of chlorine to water in an amount greater than that needed to produce the chlorine residual produced by combined residual chlorination. Now, however, superchlorination is the term commonly used for the application of sufficient quantities of chlorine to increase the rate of reactions. This practice results in excessive amounts of free residual chlorine and the water must undergo dechlorination before it may be drunk.

4. *Chlorine–chlorine dioxide treatment.* This process usually involves the application of chlorine dioxide to waters previously treated with chlorine. The combination is used, rather than chlorine dioxide alone, to reduce costs and utilize certain advantages of chlorination. Chlorine dioxide is produced at the plant site by the addition of chlorine to a solution of sodium chlorite. The recommended ratio of chlorine to technical-grade sodium chlorite on a weight basis is 1:2—or, preferably, 1:1, so that the reaction is completed by the excess chlorine, the cheaper chemical. A number of chemical reactions are reported to occur, depending on the pH of the mixture (*3*); a pH of 3.5 or lower is recommended for best results (*4*).

In order to clarify the various chlorination practices further, they are illustrated in Fig. 2. Dosages of chlorine or chlorine dioxide are plotted against the residuals they produce. These residuals are characterized as combined or free.

Upon addition of chlorine to a water containing ammonia, a combined residual chlorine is obtained. The measured residual, however, is slightly less than the theoretical.

In free residual chlorination, the immediate (zero) chlorine demand of the water must be satisfied before a free chlorine residual can be obtained. In the breakpoint process addition of chlorine results in the formation of chloramines. The type of chloramines

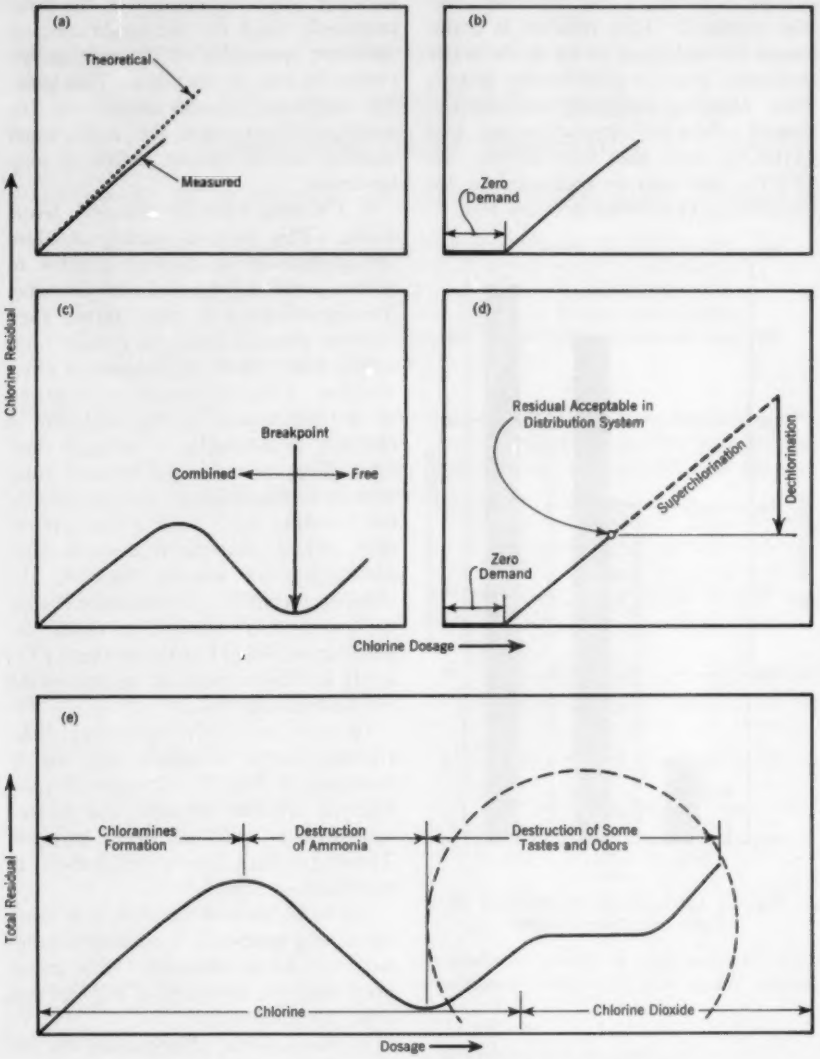

Fig. 2. Chlorination Practices for Taste and Odor Control

Parts a, b, c, d, *and* e *represent combined residual chlorination, free residual chlorination, break-point process, superchlorination followed by dechlorination, and chlorine–chlorine dioxide treatment. The graphs are only descriptive, not quantitative.*

formed depends on the pH of the water. For the pH values usually encountered, mono- and dichloramines are obtained. Once the peak is reached, further addition of chlorine results in a decrease in residual, and at the breakpoint most of the chlorine and ammonia are gone. Chlorine is converted to chloride ions, and ammonia is converted to nitrogen or nitrogen oxides. Following the breakpoint a free chlorine residual is obtained. A ratio of ammonia-nitrogen to chlorine of 1:10 (by weight) is required theoretically to attain the breakpoint, but higher ratios of up to 1:25 have been reported in practice where water was heavily polluted.

The method of superchlorination and dechlorination is also illustrated in Fig. 2. Chlorine is added in amounts that produce higher residuals than are acceptable in the distribution system. This is done in order to increase the rate of the reactions. Part of the residual must be removed by dechlorination before the water enters the distribution system. Sulfur dioxide, sodium sulfite and bisulfite, and, sometimes, ammonia are used for the dechlorination.

The method of free residual chlorination followed by chlorine dioxide treatment is also shown in Fig. 2. It is believed that the reactions involving chlorine dioxide, some chloroderivatives and other odorous materials are rapid, and that the addition of chlorine dioxide therefore does not initially show an increase in the total residual. Further addition of chlorine dioxide should result in an increased residual.

Relative Merits

All the chlorination practices have merits and can, under appropriate conditions, provide means for taste and odor control. All have been used in practice with varying success.

Combined residual chlorination is generally the least effective. The breakpoint process has many advantages where ammonia is present and the organic load is of a nitrogenous nature. Careful control should be practiced so that a true free chlorine residual can be obtained, as inadequate chlorination may intensify tastes and odors. Control may be secured by the addition of enough chlorine to insure chlorination beyond the breakpoint at all times.

Superchlorination may sometimes be advantageously used, especially when conditions do not permit long detention periods. The disadvantages of superchlorination are that large amounts of chlorine must be applied and that dechlorination is necessary before the water may be drunk.

Chlorine–chlorine dioxide treatment, the most modern of all chlorination processes, is a well established practice for treating waters containing phenolic materials, but it has also been used with success on other waters. It has been reported (*5*) that chlorine dioxide has a disinfecting ability comparable to that of chlorine. Chlorine dioxide can therefore be used as a disinfecting agent as well as a taste and odor removing agent, and one can make full use of chlorine application for removing tastes and odors and obtain further reduction by the addition of chlorine dioxide. Thus, certain chloroderivatives and other odorous materials not removed by chlorine may be reduced to odorless products with chlorine dioxide.

A combination of the various chlorination methods may be applicable at individual plants and, if properly man-

aged, may reduce costs and improve effectiveness. For example, free residual chlorination may be followed by chlorine-ammonia treatment in order to reduce the excess chlorine and provide a more stable residual in the distribution system.

Mechanism of Taste and Odor Removal

There is a mechanism common to all chlorination practices for taste and odor control. It has two major purposes: [1] to remove taste- and odor-causing substances by oxidizing them to odorless and tasteless products, and [2] to control the growth of odor-causing algae and microorganisms during treatment and distribution.

The efficiency of chlorine in the oxidation of tastes and odors and in stopping microorganism growth depends on the form of chlorine residual present. A free chlorine residual is many times more effective than a combined chlorine residual, but less effective than chlorine dioxide, which is reported to have 2½ times the oxidation capacity of chlorine.

The effectiveness of a chlorine residual also depends on its concentration during treatment. An increase in the amount of chlorine present increases the rate of the reactions and sometimes makes possible certain reactions that would not otherwise occur. It should be pointed out, however, that the oxidation reactions should go to completion, because intermediate products may only intensify taste and odors. A typical example of this is the development of chlorophenolic tastes and odors, which are well known in water treatment.

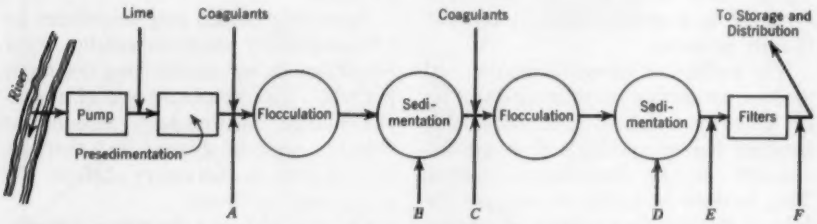

Fig. 3. Flow Diagram of Typical Treatment Plant and Alternative Points of Application in Four Chlorination Processes

Points of application are as follows: [1] *chlorine-ammonia treatment—ammonia and chlorine at* A, *or ammonia at* B *and chlorine at* C, *or ammonia at* E *and chlorine at* F; [2] *free residual chlorination—chlorine at* A, C, *or* D; [3] *superchlorination and dechlorination—chlorine at* C *or* D *and dechlorination at* E; [4] *chlorine–chlorine dioxide treatment—chlorine at* A *and chlorine dioxide at* E *or chlorine at* C *and chlorine dioxide at* F.

Other factors to be considered in the design of taste and odor removal facilities include the quality of the water under treatment (especially pH, temperature, and the quantity and type of organic matter), the detention times that can be provided, and other processes involved in the plant operation.

Points of Application

In the water treatment plant there are a number of points at which chlorine and other chemicals may be applied for taste and odor control. Dis-

infection is usually practiced jointly with taste and odor control. In selecting the proper points of application, one should consider local conditions as well as other factors: [1] the necessity for adequate detention time and optimum pH conditions; [2] the need for control of algal and microbiological growths throughout the plant, as the growths may intensify tastes and odors; and [3] the possibility of correlation of taste and odor control methods with conventional treatment processes, such as coagulation, by injection of chemicals at the proper points.

In Fig. 3 a schematic flow diagram of a treatment plant employing taste and odor control is shown. This diagram includes presedimentation and is most typical of plants treating Missouri River water. It is impractical to indicate all the points where chlorine and other chemicals for taste and odor control can be added, but the more popular alternatives are presented.

Design Criteria

Certain important factors that should be considered in the design of taste and odor removal facilities that use chlorine and its derivatives are:

1. The quality of water (threshold odor, ammonia content, pollution, pH, and temperature)
2. The degree of treatment required to produce a palatable water
3. The availability and cost of chemicals
4. The most suitable chlorination process for the given conditions (Laboratory and pilot plant studies should be utilized for this purpose.)
5. The proper points of application, which depend on the detention time required, the most effective use of other treatment processes, and the thorough mixing of the chemicals with the water
6. The type, condition, and size of the distribution system
7. The maximum level of chlorine residual that can be maintained without causing tastes and odors (The possibility of development of tastes and odors in the distribution system should also be considered.)
8. The accuracy, availability, and dependability of the control methods
9. Overall cost considerations.

The best solution to an individual problem can be found only through consideration of local conditions. To insure best results, laboratory tests should be made to evaluate the applicability of each process to the particular water and plant.

New Approach

The increasing prevalence and severity of odor problems in water supplies are evidence that a fresh approach is necessary. In the past, taste and odor problems and disinfection have commonly been handled together. Although disinfection has been studied extensively, taste and odor problems have not. There is a need for further investigation of the effectiveness of chlorination practices in removing odors.

Two major investigations are now in progress at the sanitary engineering laboratories of Washington University. First, studies are being made of organic material of taste and odor significance extracted from raw and finished Missouri River water. Second, the effectiveness of certain chlorination practices in removing substances causing tastes and odors is being investigated. It is believed that these studies will eventually make it possible to define taste and odor problems and will

provide a sound basis for their final solution.

Laboratory investigations to evaluate certain chlorination practices in solving the problem of taste and odors have been made possible by the sponsorship of the St. Louis County Water Co. These studies are concerned principally with the rate and degree of removal of ammonia, organic nitrogen, phenol, and organic extracts when chlorine or chlorine dioxide is used as the oxidizing agent. Simplified water systems and actual Missouri River water systems have been used. The parameters studied include: threshold odors, ammonia and organic nitrogen content, chemical oxygen demand, and carbon content.

Conclusions

Chlorine and its derivatives have been reported to remove tastes and odors from water supplies with various degrees of success. Certain design criteria are important in the application of chlorination techniques for taste and odor control. Further evaluation of the use of chlorine and its derivatives in removing tastes and odors from water supplies is needed. A new approach in which direct parameters are used is recommmended.

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Removal of Hydrogen Sulfide From a Ground Water Supply

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A paper presented on Apr. 23, 1959, at the Kansas Section Meeting, Pittsburg, Kan., by Leonard L. Sammons, Chief Chemist, Sammons Medical Lab., Pittsburg, Kan.

ALTHOUGH the appearance of hydrogen sulfide as a natural constituent of a ground water supply is not a common problem, it is an important one in certain areas. Pittsburg, Kan., located in the midst of a coal-mining area, obtains its raw water from deep well sources pumped through shale, sulfur deposits, and some sandstone formation. In the water of this city, the presence of hydrogen sulfide is significant. Little information, however, is available on ways to eliminate its effects.

Properties

Hydrogen sulfide is one of the many naturally occurring sulfur compounds. It is commonly identified as the substance that gives off an odor of rotten eggs and turns silverware black. It is a colorless gas, heavier than air, and moderately soluble in water (about twice as soluble as carbon dioxide). In concentrated form it is poisonous if inhaled. A dose of 1 part hydrogen sulfide per 20,000 parts of air causes marked symptoms in human beings, such as nausea, headaches, and dizziness. A stronger dose of 1 part hydrogen sulfide per 1,000 parts of air results in a rapid loss of consciousness.

The main reason for removing hydrogen sulfide from drinking water is because of its offensive taste and odor. Another reason is that water with a fairly high hydrogen sulfide content is very corrosive to most surfaces with which it comes in contact, including stainless steel surfaces, which are not usually subject to corrosion.

Aeration

In dealing with the problem of removing hydrogen sulfide in the water treatment plant, it should be remembered that concentrations of gases normally present in air will equalize with concentrations of the same gases dissolved in water exposed to air for an appreciable period of time. The temperature of the water and the atmospheric pressure control the solubility of these gases. Aeration exposes a large surface of water to air and brings about the transfer and diffusion of gases. The intensity of the odor of hydrogen sulfide dissolved in water can be reduced by aeration.

In the Pittsburg treatment plant, water enters an aeration chamber from the discharges of four wells. The pumps are alternated so that each well is pumped for a few hours each day, regardless of water demand. It has been found that a well not pumped each day for at least a few hours will build up a hydrogen sulfide content and accumulate black water in the well casing. Each discharge casing ex-

tends up into the air chamber for about 10 ft. On the end of each casing large spreader heads have been installed. The chamber is so constructed that a blast of air is forced through the falling water coming off these spreaders. This air is supplied by a 20,000-cfm fan with a wind tunnel connected at the base of the aeration chamber. The gas removed is exhausted through an opening at the top of the air chamber. The raw water coming in contains about 5 ppm hydrogen sulfide; aeration reduces it to about 1 ppm. Additional aeration is accomplished by keeping the water in the clarifier at such a level that an even flow and drop over the weirs are obtained. Hydrogen sulfide not removed in the air chamber is quickly oxidized to free sulfur by the dissolved oxygen in the aerated water. If the free sulfur is not removed, it may revert to hydrogen sulfide through the action of certain microorganisms.

Coagulation and Sedimentation

The coagulation and sedimentation resulting from the application of lime and alum bring the concentration of hydrogen sulfide down to about 0.2 ppm on the top of the filters. But water containing as little as 0.2 ppm hydrogen sulfide not only has a bad taste and odor, but also causes difficulties in photography shops. Photographic film washed with this water will be stained brown.

The concentration of precipitated sulfur is eventually reduced by filters and chlorine treatment to 0.0 ppm. When the chlorine concentration in the finished water is kept between 0.15 and 0.35 ppm, a zero reading for hydrogen sulfide is obtained.

Prior to 1954, raw water from Pittsburg wells was used to lubricate the pump rods. It was found that if the wells were down for 6 hr or more, the rods froze from the corrosive effect of hydrogen sulfide. This condition was brought about by the buildup of hydrogen sulfide when the wells were not pumped, as mentioned before. All valves and grease were affected by this raw water. Since 1954, however, the use of raw water to lubricate pump rods has been discontinued; only treated water has been used. It is believed that this changeover has eliminated 50 per cent of the difficulty with pump rods.

Poisoning of Wild and Domestic Animals by a Toxic Waterbloom of *Nostoc rivulare* Kuetz

Floyd F. Davidson

A contribution to the Journal by Floyd F. Davidson, Prof., Dept. of Biology, Baylor Univ., Waco, Tex. This investigation was supported by Research Grant E-1429 (C2) from the National Institute of Allergy & Infectious Diseases, National Institutes of Health, USPHS, Washington, D.C.

THE first recorded occurrence of a toxic waterbloom was described in 1878 by Francis (*1*). He positively related the death of domestic animals to an algal bloom of *Nodularia pumengia* Mert from Lake Alexandria in southern Australia. During the following 80 years, similar manifestations were reported from South Africa (*2–7*), Alberta (*8, 9*), Manitoba (*10*), Ontario (*11, 12*), Bermuda (*13*), and the United States. In the United States, studies of waterblooms and their relationship to illness and death among wild and domestic animals have been limited to those waterblooms found in the lakes of Michigan (*14*), Minnesota (*15–22*), North Dakota (*23, 24*), Iowa (*25, 26*), Montana (*27*), Ohio (*28, 29*), Colorado (*30*), Kentucky (*22*), and Wisconsin (*31*). Human reactions attributed to waterblooms have been reported from West Virginia (*32*), national parks in the northwestern United States (*33*), and the District of Columbia (*34*). Reactions to specific groups of algae were reported from Wisconsin (*35, 36*) and Pennsylvania (*37*).

The literature contains no record of the occurrence of poisonous waterbloom in the southwestern United States. Doubtless, there have been outbreaks of algal poisoning in central Texas that have not been reported. Although in this area, these waterborne organisms are considered neither a serious menace to livestock nor a public health problem, the potential economic loss and danger to man from algal poisoning should not be minimized.

Six genera of Cyanophyta are known to possess species that are toxic to wild and domestic animals: *Microcystis, Anabaena, Aphanizomenon, Nodularia, Gloeotrichia,* and *Coelosphaerium.* Two of these genera, *Microcystis* and *Anabaena,* were implicated in human reactions (*36, 37*). Heise (*35*) attributed two cases of allergy to members of the subgroup Oscillatoriaceae, the genera of which were not mentioned. According to Heise, these blue-green algae are injurious also to fish and livestock. Most human reactions reported, however, were attributed to the general group of waterblooms.

In most cases of animal reactions, the neuromuscular and respiratory systems were involved. Manifestations in man were in the form of local allergic eruptions, systemic allergic reactions, or dysenterial disorders. Laboratory investigations have been limited prin-

cipally to studies on the morphologic changes produced by poisonous algae and to the establishment of the minimal lethal dose for certain laboratory animals. A few attempts have been made to isolate and characterize the toxins (*2, 18, 22, 38–40*). There are limited quantitative data on the relationships of different cyanophycean genera to illness or death of animals. Such additional data are necessary in order to present an overall picture for the United States (*29*).

This article describes an outbreak in Texas of algal poisoning attributed to *Nostoc rivulare* Kuetz,* an alga heretofore considered to be nontoxic. Wild and domestic animals that drank pond water containing a heavy accumulation of this alga became ill or died. Quantitative data on some of the physiologic effects of *N. rivulare* Kuetz or its extract on albino mice are also presented.

Field Observations

In August 1956, 1957, and 1958, a luxuriant waterbloom appeared on a stock pond near Waco, Tex. The pond, which had no outlet, stored the runoff water from a nearby dairy and poultry farm. The temperature of the water was 30°–35°C, the pH was 7.8–9, and the maximum depth of the water was 20 ft. Livestock and wild animals waded in the shallow areas where the suspended algae were concentrated into a jelly-like mass approximately 15–20 cm in depth. Numerous dead fish and frogs were observed along the waterline near the heaviest bloom (Fig. 1, top). Others floated on the surface and appeared to be intoxicated. Chickens, ducks, turkey, and cattle that drank the algae-infested water died within a few hours or became acutely ill. The accompanying symptoms, which included restlessness, repeated swallowing, blinking of the eyes, and convulsions, were similar to those that have been described for a number of toxic waterblooms. The concentration of *N. rivulare* in the bloom was extremely high, with almost complete exclusion of plankton.

Microscopic examinations of the intestinal content of dead frogs and fish for the presence of *N. rivulare* were negative. The intestinal tract of fowl, however, contained large quantities of the alga. No autopsies were made on mammals in the field.

In order to test the toxicity of the fresh algae, 2 ml of the heavy suspension was injected intraperitoneally into each of five albino mice in the laboratory. The symptoms manifested by the mice, though more acute, were similar to those described for mammals in the field. All the mice died within 2 hr.

Laboratory Studies

The purpose of the following laboratory test was to obtain quantitative data on some of the physiologic effects of crude *N. rivulare* or its extract on albino mice. The mice used were of either sex and of indeterminate strain. They were maintained on special feed † in a room thermostatically controlled at 22°–24°C. At the beginning of the experiments, the mice were 86–88 days old and weighed 30–35 g.

* Identification made by Francis Drouet, Cryptogamic Herbarium, Chicago Natural History Museum, Chicago, Ill. (Present address: Department of Biology, Highlands University, Las Vegas, N.M.)

† Purina Laboratory Chow, a product of Ralston Purina Co., St. Louis, Mo.

Algal Extracts

Preparation. Masses of *N. rivulare* comprising the waterbloom were transferred to the laboratory and fan-dried at a temperature of 30°C for 24 hr, powdered in a power blender, and stored in sealed containers at room temperature (*41*). The algae thus prepared retained their toxicity for more than 3 years.

The three extracts tested were prepared from preserved algae. These preparations were designated as: [1] crude extract, [2] aqueous extract, and [3] aqueous filtrate. Crude extract was prepared by ball milling a sample of preserved algae that were dry for 12 hr and in twice-distilled water for 1 hr. The mass was further reduced in a tissue grinder to a finely dispersed homogeneous suspension. The amount of the toxic factor in the extract was unknown. Hence, its concentration could be expressed only as the weight of the algae per volume of solvent used. The crude extract was not bacteria free.

For the preparation of aqueous extract and aqueous filtrate, previous procedures were followed (*41*). Samples of these extracts tested on nutrient media for the presence of bacteria were negative.

Administration. The first series of tests was designed to determine the effects of the three extract preparations on albino mice when administered orally with food or drink, injected intraperitoneally or subcutaneously, or applied externally to the skin.

Crude extract was prepared at a concentration of 10 mg of algae per 1 ml of water. Three mice that had been deprived of water for 2 days were given the extract as the only drink for 21 days. A mixture of 10 ml of crude extract and 10 g of laboratory animal feed was fed to three other mice for 21 days. The algae-treated food and water were ingested as readily as the untreated.

Each of six mice was injected with 2 ml of crude extract—three mice intraperitoneally and three subcutaneously. A shaved area, 3 cm in diameter, on the backs of three mice was treated with the crude extract at intervals of 2 hr for a period of 12 hr.

Corresponding concentrations of aqueous extract and aqueous filtrate were administered in the same manner as the crude extract. Sterilized syringes and needles were used throughout. Controls were provided for each test. All experimental animals and controls were observed continuously for 24 hr and at 12-hr intervals thereafter. The results of these tests, shown in Table 1, indicate that the extracts (in the dosage given) were nontoxic when administered in food or drink. Fitch and colleagues (*18*) observed that fresh samples of *Microcystis* and *Anabaena,* when administered in food, produced death in laboratory animals in a short time. When the algae were dried, however, it was practically impossible to destroy an animal by such feeding, but it could be destroyed quickly by intraperitoneal inoculation of the same dosage.

Reactions. The reactions of the mice to intraperitoneal injections of lethal doses of crude extract were uniform. There was a latent period of approximately 30 min, followed by restlessness and jerky body motions. No food or water was taken, and no defecation or urination was observed. There was evidence of blindness, accompanied by moderate lacrimation

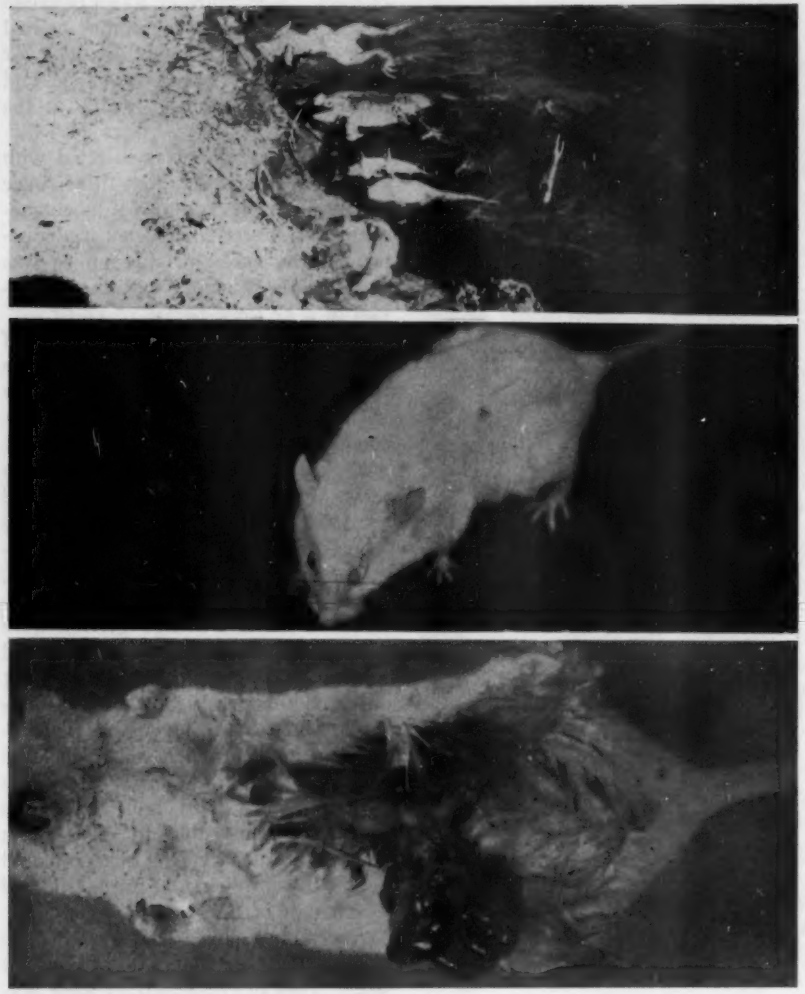

Fig. 1. Effects of *Nostoc rivulare* or Its Extract on Fish, Frogs, and White Mice

Top: Frogs and various kinds of fish killed by fresh N. rivulare *in an open pond. Center: Atrophy of the left eye of a mouse after an intraperitoneal injection with aqueous extract of* N. rivulare. *Within 2 weeks, the eye began to atrophy, and by the end of the third week, it had completely degenerated. Bottom: Evisceration and necrosis of the skin of a mouse after an intraperitoneal injection with crude extract of* N. rivulare.

and rapid twitching of the eyelids. The final stage was characterized by a stiffening of the limbs, swelling of the abdomen, convulsions ending in prostration, rapid breathing, and death. At the time of death, the entire body was extremely rigid; relaxation never occurred.

Autopsy within 5 min after death revealed the accumulation of a greenish-yellow liquid in the lungs and peritoneal cavity. The intestinal tract was filled with hard, partially digested food. The urinary bladder was empty, and the kidneys were light in color. The liver and spleen were enlarged and hard; and there was an odor of putrefaction.

Various reactions were observed in mice injected intraperitoneally with sublethal doses of crude extract. All cases showed restlessness, impairment of the urinary and digestive functions, excessive blinking of the eyes, and poor vision. The abdomen was swollen and the fur ruffled. No food or drink was taken. These symptoms diminished after 8–10 hr. Food and water were then taken, defecation and urination were observed, and normal sight was apparent in most animals. The animals appeared to be normal, except for their swollen abdomens and ruffled fur. Evisceration occurred in two of the animals approximately 24 hr after the injections. The muscle wall of the abdomen was ruptured and the injected algal material and the accumulated abdominal liquid were released into the subcutaneous tissue. Necrosis of the skin occurred (Fig. 1, bottom), followed by evisceration through the ruptured musculature. One of the mice lived for 48 hr after evisceration. Its death was apparently the result of bacterial infection of the extruded viscera. The second mouse was killed. The left eye of one mouse injected with a sublethal dose of aqueous extract showed signs of atrophy within 2 weeks, and by the end of 3 weeks, the eye had completely degenerated (Fig. 1, center). Animals that survived the immediate effects of intraperitoneal injections of aqueous extract or subcutaneous injections of

TABLE 1

Reactions of Albino Mice to Extracts of Nostoc rivulare *Administered in Different Ways*

Method of Administration*	Crude Extract	Aqueous Extract	Aqueous Filtrate
Drink	hair ruffled, nervousness	no symptoms	no symptoms
Food	hair ruffled, nervousness	no symptoms	no symptoms
Intraperitoneal injection	2 eviscerations at 24 hr; 1 death at 6 hr; all dead within 48 hr	nervousness in 2; 1 with atrophied eye at 21 days	3 with tumors on shoulders at 6 mo
Subcutaneous injection	3 with tumors on shoulders at 3 mo	hair ruffled, nervousness	hair ruffled, nervousness
Cutaneous application	heavy scales at 24 hr, scales shed at 96 hr	no symptoms	no symptoms

* The control mice, administered distilled water with each method, showed no symptoms.

crude extract, developed large tumors on their shoulders and backs within 3 months and died within 9 months. The remainder of the experimental animals showed no reactions.

External applications of crude extract produced heavy scales on the shaved skin of the mice. The scales were shed in 4 days, and the hair grew again within a few weeks. External applications of aqueous extract or aqueous filtrate produced no ill effects. Shaved, untreated skin remained normal.

Toxic Factor

Heat stability. Duplicate series of crude extract were prepared in water as described previously, each series containing eight concentrations: 0.08, 0.40, 1.20, 1.60, 2.00, 4.00, 6.00, and 8.00 mg of algae per 1 ml of water. One series was autoclaved at 15 psi of pressure for 20 min; the other series was employed unautoclaved. Each of eight mice was weighed and given an intraperitoneal injection of 2 ml of one of the concentrations in the autoclaved series. Eight mice were likewise injected with the unautoclaved series. The ratios of the weight of algae used to the weight of the mice in each series were: 0.0231, 0.0534, 0.0742, 0.0933, 0.1300, 0.3600, 0.4100, and 0.5400 mg of algae to 1 g of body weight. Each of three mice was injected intraperitoneally with 2 ml of sterile distilled water; these mice were used as controls. The results of the tests are shown in Table 2.

The minimal lethal dosage in the unautoclaved series was 0.0933 mg of algae per 1 g of body weight. Sublethal doses produced symptoms of algal poisoning that subsided, after which the animals recovered. Tumors appeared on the shoulder and abdominal regions of the mice within 6 months. Dosages of, or greater than, 0.0933 mg of algae per 1 g of body weight killed mice in 15–60 hr, depending on the concentration of the injections. Mice injected with distilled water showed no symptoms. Those injected with the autoclaved series of concentrations also showed no symptoms.

Under the conditions of these tests, therefore, it may be stated that the toxic factor is unstable when autoclaved and that the minimal lethal dosage in mice is 0.0933 mg of algae per 1 g of body weight.

TABLE 2

Effects of Unautoclaved Nostoc rivulare *Crude Extract* on Albino Mice*

Algae Concentration *mg/ml H_2O*	Algae Dosage† *mg/g body weight*	Effects
0.08	0.0231	typical symptoms of
0.40	0.0534	algal poisoning; all
1.20	0.0742	survived, all with tumors at 3 mo
1.60	0.0933	death at 60 hr
2.00	0.1300	death at 23 hr
4.00	0.3600	death at 15 hr
6.00	0.4100	death at 26 hr
8.00	0.5400	death at 15 hr

* Both the autoclaved crude extract and the distilled water given to controls had no effect.
† Administered by intraperitoneal injection.

Origin. Bishop and associates (*42*) and Hughes and associates (*43*) detected a slow-death factor in cultures of *Microcystis aeruginosa* that they atttributed to bacterial contaminants. This factor is in addition to the fast-death factor that was found to be algal in origin. To determine whether the bacterial associates of *N. rivulare* exhibited toxic properties, mixed cultures

of these bacteria were established in standard nutrient broth, 12-hr cultures were centrifuged, and the heavy layers of bacteria were removed and washed in two changes of normal saline. The bacteria from two cultures were combined and mixed with 3 ml of normal saline. A suspension of 2 ml of the living bacteria in normal saline was injected intraperitoneally into each of three mice. Bacteria from the remaining two cultures were combined and suspended in 3 ml of 70 per cent alcohol and allowed to stand for 1 hr. After the suspension was centrifuged, the bacteria were washed in two changes of and suspended in 3 ml of normal saline. Tests for living bacteria at this stage were negative. Then, 2 ml of the dead bacteria suspended in normal saline was injected intraperitoneally into each of three mice. The mice showed no symptoms, indicating that bacterial associates of *N. rivulare* had no toxic properties.

The toxicity both of crude extract of *N. rivulare* containing living bacterial associates and that containing dead bacteria was also tested. A total of 15 mg of preserved algae was ground in a ball mill and suspended in 3 ml of normal saline by means of a tissue grinder. Then, 2 ml was injected intraperitoneally into each of three mice. In addition, 15 mg of preserved algae was ground in a ball mill and supended in 3 ml of 70 per cent alcohol for 8 hr. The alcohol was evaporated at reduced pressure, and the residue was suspended in 3 ml of normal saline. After tests on nutrient media showed the suspension to be free of living bacteria, 2 ml was injected intraperitoneally into each of three mice.

Crude extract, with a concentration of 5 mg of algae per 1 ml of water, that contained living or dead bacterial associates was lethal. Extract with living bacterial associates produced typical symptoms of algae poisoning in mice, with one death at 18 hr and two deaths within 19 hr. Extract with dead bacterial associates likewise produced symptoms of algae poisoning, with one death at 6 hr and two at 8 hr. Treatment of the algae with alcohol could have rendered the toxic factor more soluble in water, and consequently more readily absorbed by the body. These tests show that there is no slow-death factor in *N. rivulare* and that the toxic factor is algal in origin.

Physiologic Changes Produced by N. rivulare

The general symptoms of algal poisoning reported include hypothermia, hyperglycemia, tachycardia, and a number of other physiologic changes. Quantitative data relative to these changes, however, are not included in the literature.

Each of fourteen mice was given an intraperitoneal injection of a lethal dose of crude *N. rivulare*. Two mice were kept as untreated controls. Six treated mice were examined throughout the tests for changes in body temperature, rate of heartbeat, and respiration rate at 6-, 8-, and 10-hr intervals after injection. Six were subjected to blood tests and urinalysis. The results of these tests are shown in Tables 3 and 4.

During the first 10 hr after injection, body temperature dropped 20.8°F. The rate of heartbeat, measured by an electrocardiograph, was reduced by 180 beats per minute. The respiration rate increased by 60 per minute. Although some authors (*44*) indicated an increase in blood sugar in many animals as a result of algae poisoning,

in the present tests there was a decrease in blood sugar of 19 mg/100 ml blood after the 10-hr interval. The Folin-Wu method (*45*) was used for determination of blood sugar. The blood coagulation time was reduced from 5 min to 3 min. Red blood cell counts were successfully made on the controls and treated animals at the end of 6 hr, at which time the count was reduced by 2,500,000 red cells per 1 ml of blood.

The results of these tests coincide with the general symptoms of algal poisoning reported for other animals, with the exception of the blood sugar

TABLE 3

Physiologic Effects of Intraperitoneal Injections of Nostoc rivulare *Crude Extract on Albino Mice*

No. of Mice	Time After Injection *hr*	Body Temperature °F	Heartbeat *beats/min*	Respiration *rate/min*
8	Untreated	98.8±0.8	720±2	160±1
6	6	94.5±1	660±1	175±2
6	8	86.0±0.9	600±2	188±3
6	10	76.0±0.8	540±1	220±1

experiments. Repeated tests on injected mice, however, confirmed the above results.

Discussion

These field observations and laboratory tests describe the toxic properties of *Nostoc rivulare,* adding another genus to the six Cyanophyta already known to possess toxic species. The plant mass of this species is relatively large, gelatinous, and fragile. In the early stage of formation the mass is spherical, but later becomes torn and irregularly expanded. The filaments are flexuous and loosely entangled. It is distinguished from its near relatives by the shape of the gonidia and by the size of its trichomes (*46*).

It is well known that runoff water from agricultural areas, such as that stored in the pond referred to under "field observations," is rich in nitrogen and phosphorus compounds (*47*). The temperature, pH, and chemistry of the drainage water, combined with other favorable ecologic conditions, were apparently ideal for the luxuriant growth of *N. rivulare.* Other bodies of water that received runoff water from nonagricultural land in the same area, however, did not develop waterblooms.

TABLE 4

Effects of Intraperitoneal Injections of Nostoc rivulare *Crude Extract on Albino Mouse Blood*

No. of Mice	Time After Injection *hr*	Amount of Blood Sugar *mg/100 ml blood*	Coagulation Time *min*	Red Cell Count *1,000,000/ml blood*
8	Untreated	125	5	8.5
2	6	123	3	6.0
2	8	108	3	
2	10	106	3	

The general symptoms of *N. rivulare* poisoning parallel the reported reactions produced by many other toxic cyanophycean species. The latent period following the ingestion of fresh *Nostoc* by wild or domestic animals, or following intraperitoneal injections in mice, was longer than for other toxic species. The cause of death in piscian and amphibian life in the algae-infested water is difficult to determine. Some workers (*47, 26*) are of the opinion that the death of fish in heavy waterblooms is due to a decline in the dissolved oxygen or to hydroxylamine, a poisonous substance produced from the decay of certain

blue-green algae. There is also convincing evidence in the literature that fish are poisoned by toxic substances from some living blue-green algae or from their exudates, in which there is no indication of decomposition. In the present study, it is possible that any one or even a combination of factors could have been involved. Inasmuch as the fish and frogs had access to a large portion of the pond that was relatively free of suspended algae, and because a number of floating bass and crappie taken from this area exhibited symptoms of intoxication, it is more likely that they were poisoned by a toxic substance produced by the living algae. Schools of small catfish trapped in puddles along the shore as the water receded were intoxicated, although the concentration of algae was too low to influence the oxygen level appreciably. The absence of algae in the intestinal tract of the fish and frogs, however, would indicate that other factors might have been involved.

In addition to the typical symptoms of algal poisoning, several other symptoms were manifested by albino mice. Poisoning by other cyanophycean species did not affect urination or defecation, while *N. rivulare* inhibited these processes. It is probable that the greenish-yellow liquid that accumulated in the abdominal cavity came from the surrounding organs and tissues. This would account for the fact that the liver was extremely hard; the intestinal tract was filled with hard, undigested food; and the urinary bladder was empty. The function of these organs would thus be impaired. The loss of sight produced by lethal doses, the atrophy of the eye by a sublethal dose, and the paralysis of the hindquarters indicate the presence of a neurotoxic substance in *N. rivulare*.

Summary

The poisoning of wild and domestic animals by a waterbloom of *Nostoc rivulare* Kuetz from a pond in central Texas has been described. Cattle, fish, frogs, and fowl that drank the water containing a heavy growth of the alga became acutely ill, and many died within a short period of time. Most of the accompanying symptoms were similar to those described for a number of other toxic waterblooms. Intraperitoneal injections of albino mice with fresh algal material or with extracts prepared from preserved material produced symptoms that were uniform. The characteristic symptoms were restlessness, increased respiratory rate, renal and intestinal disorders, decrease in blood sugar, decrease in blood coagulation time, decrease in red blood cell count, increase in the rate of heart beat, and paralysis of the hindquarters. Subcutaneous injections resulted in complete necrosis of the abdominal wall, including the skin. The mice that survived developed tumors on the shoulders; two experienced evisceration; and the eye of one completely atrophied.

The minimal lethal dosage of the fresh alga was found to be 0.0933 mg/1 g of body weight in mice. The toxic factor was soluble in ethanol or water and was rendered inactive when autoclaved at 15 psi pressure for 20 min. It affects the neuromuscular and respiratory systems of albino mice.

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1955–56 Infectious Hepatitis Epidemic in Delhi, India

Joseph M. Dennis

A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Joseph M. Dennis, San. Engr., Region VII, USPHS, Dallas, Tex.

AN explosive epidemic of infectious hepatitis started in Delhi, India, during the first week of December 1955, and lasted about 6 weeks, reaching its peak on Dec. 27. It was the largest epidemic of infectious hepatitis that has ever occurred. Because of the magnitude of the outbreak, a special study was made to determine its cause and actual extent. A committee appointed to investigate the outbreak issued a report in which the source of the epidemic was given as the Delhi treated water supply. An extensive series of articles on the epidemic was published as a special issue of the *Indian Journal of Medical Research* (*1*). As these publications may not be readily available, the salient features of the epidemic are summarized from the above references.

This was the first well documented epidemic of infectious hepatitis involving a treated water supply, although a number of smaller outbreaks of the disease have been attributed to untreated well and surface supplies. The epidemic should thus be of unusual interest to sanitary engineers and water utility operators. What circumstances in Delhi in late 1955 made this outbreak possible? What precautions are necessary to prevent a recurrence?

Severity of Epidemic

Although infectious hepatitis was not a reportable disease in 1955, it was known to be highly endemic with an annual morbidity rate in India of the order of 300–400 cases per 100,000 population per year (*1*). The rate in the United States is somewhat less than 20 per 100,000. The 1955–56 outbreak was explosive and the epidemic curve was characteristic of a common source infection. Some 7,000 cases were reported to the health authorities during the epidemic, and a sample survey indicated that the total number of cases of jaundice must have been in the neighborhood of 29,300 in a total population of 1,700,000. The authorities estimated the total number of infections at 1,000,000. The distribution of reported cases in the several political entities which comprise Delhi (Fig. 1) together with the source of water supply are shown in Table 1.

From an inclusive study of the evidence, the epidemiologists and the official investigating committee found that the outbreak was caused by heavy contamination of the raw water of the Chandrawal treatment plants during Nov. 10–16, 1955. The fact that no undue incidence of typhoid or dysentery occurred during this period indicated that the water treatment

processes were adequate to deal with bacterial pathogens but not adequate to remove or kill the virus of infectious hepatitis. Table 2 shows the incidence of enteric diseases among government employees and their families in Delhi from July 1955 to June 1956.

Water Sources

Water for Delhi is taken from the Jumna River, which has its head waters in the Kallash Range of the Himalaya Mountains. The Jumna River flows south through the state of Punjab, then eastward to join the Ganges River at Allahabad in the state of Uttar Pradesh. Records show that the flow of the Jumna River at Delhi has exceeded 200,000 cfs. Except for short periods during the monsoon seasons, in the spring and fall, the river flow varies between 200 and 3,000 cfs. During the irrigation season most of the flow of the river is diverted 180 mi above Delhi to the canal systems of Punjab and Uttar Pradesh. What flow there is at Delhi during these dry periods is return flow, ground water seepage, and excess of that required for the canals.

The chemical and bacteriological quality of the Jumna River water is not materially different from that of American surface streams. Table 3 gives data on the general quality of these waters during the year.

The water is treated in three filtration plants before distribution. The first plant, called Chandrawal No. 1, began operation in the early 1920's. In 1953, Chandrawal No. 2 was built near Chandrawal No. 1 on a site that permits expansions as demand for water increases. A small plant was built about the same time at Okhla in South Delhi by the ministry of rehabilitation for a large number of refugees from East Pakistan.

TABLE 1

Distribution of Reported Cases During Infectious Hepatitis Epidemic, Delhi, Dec. 1, 1955–Jan. 17, 1956

Municipality	Population 1,000	Cases per 1,000	Water Source
New Delhi	300	4.1	Chandrawal No. 1 and 2
Delhi	1,100	2.3	Chandrawal No. 1 and 2
Notified Area	100	6.0	Chandrawal No. 1 and 2
South Delhi	106	0.7	Okhla and wells
West Delhi	100	0.5	wells and Chandrawal No. 1
Shahdara	80	0.4	wells

Wazirabad Intakes

The Wazirabad raw-water intakes are located about 700 ft upstream from the Najafgarh Nallah. The latter is a small stream some 30 mi long and draining an area of about 200 sq mi. It receives sewage from about 40,000 persons and industrial wastes from a DDT plant, a fertilizer plant, and a textile mill. Water flows by gravity from the intake structures to the pumping station, where it is lifted 45

ft to rectangular desilting basins. From the latter it flows through aqueducts to the Chandrawal treatment plants.

Since the 1930's the water supply authorities have had considerable difficulty after each monsoon period in maintaining the channel to the Wazirabad intakes on the right bank of the Jumna River. Each year the British engineers, and, later, the Indian authorities, conducted water across the sand bar to the raw-water pumping station. It was found that the channels could be more easily maintained if they were on the downstream side of the river intakes, as the river dropped most of its load of fine silt and sand when the current was changed by 180 deg.

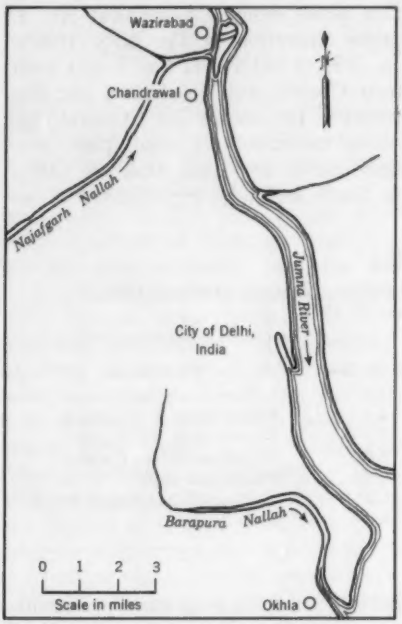

Fig. 1. Jumna River Area, Delhi, India

The falling stage of the Jumna River and the discharge of sewage from the Najafgarh Nallah were the cause of intense pollution of the Delhi water supply and led to an epidemic of infectious hepatitis that raged from December 1955 on into January 1956.

The difficulty of upstream channel construction and maintenance became critical when hand labor and mechanical dredging equipment could no longer keep up with the falling river stage. Channels that had been laboriously opened during the daylight hours quickly silted up at night. In the fall of 1956 and summer of 1958 the raw-water pumps had to be stopped when water could no longer be kept flowing in the channels to the intake structure.

Treatment Plants

The original treatment plant at Chandrawal No. 1 consisted of slow sand filters. These were later converted to presettling tanks that were used only during the monsoon periods to settle out large amounts of fine sand. The plant, located 1½ mi downstream from the Wazirabad pumping station, was expanded several times until, in 1955, it was processing 42 mgd.

Alum solution was fed to the water from constant-head dosing tanks. The water was then discharged over a partially submerged measuring weir to long, rectangular, baffled coagulation channels. The detention period in these channels was rather short and variable, as most of the time they were largely filled with fine sand and silt. From the coagulation channels the water would flow through evenly spaced circular ports to sixteen rectangular, plain settling basins with a total surface area of 2.3 acres. The theoretical detention time of the basins

TABLE 2

Typhoid, Dysentery, and Infectious Hepatitis Among Central Government Employees and Their Families in Delhi, July 1955–June 1956

Year and Month	Cases Reported—*No.*		
	Typhoid	Dysentery	Hepatitis
1955			
July	168	3,895	140
August	220	4,557	129
September	281	4,627	110
October	240	4,202	78
November	171	3,447	88
December	215	3,602	1,478
1956			
January	181	3,760	1,183
February	133	3,422	140
March	184	4,359	139
April	182	4,573	62
May	226	4,394	60
June	206	4,376	36

was 6.0 hr at a flow of 42 mgd, and the surface loading was 420 gpd/sq ft.

The clarified water was then passed to twenty 20×18-ft, ten 32×25-ft, and ten 19×23-ft, gravity rapid sand filters. All filters were of much the same design. Siphon overflows and air agitation were included in the design of the newer 32×25-ft filters. The older, 20×18-ft filters were not equipped with rate-of-flow indicators or loss-of-head gages. The rate of filtration in the newer filters could be changed by the lowering of a telescopic valve in the inspection chamber of each filter. The water level in these chambers controlled the rate of filtration by means of float valves on the effluent lines.

The filters generally had 24–30 in. of sand supported on a layer of graded gravel. The underdrains were constructed either of cast iron or of asbestos-cement. The filters were designed for backwashing at a 19-ipm rate of rise. Before being backwashed, the filters were expanded and agitated with compressed air to conserve wash water, but the operation had to be controlled carefully to prevent damage to the filters.

The siphon overflows on the newer, 32×25-ft units drained off the last traces of turbidity before the filters were put back into service. The siphons were located about 4 in. above the unexpanded filter media and were used in conjunction with a low wash water rise of 8 ipm.

Chlorination equipment in 1955 included two 96-lb/day, one 48-lb/day, and one 60-lb/day venturi gas machines and one 80-lb/day unit. The chlorination facilities permitted a maximum dosage of 1.08 ppm at 42 mgd. Chlorine was normally added to the filtered water only. If higher dosages were desired it was customary to place chlorine cylinders at several points in the plant and to bubble chlorine gas through the water in copper delivery tubes. This method of feeding chlorine was unsatisfactory, as it was not easily controlled and large amounts of chlorine were lost to the atmosphere. A 0.2-ppm dose of ammonia was formerly used in conjunction with the chlorine to produce a combined chlorine residual. This practice was stopped in 1956.

TABLE 3

Quality of Jumna River at Wazirabad, January–September 1959

Item	Minimum	Median	Maximum
Turbidity—*ppm*	32	64	2,147
Total alkalinity—*ppm*	69	123	139
pH	7.8	8.2	8.7
Coliform bacteria—MPN/100 ml	200	700	63,000

High-lift pumps at Chandrawal No. 1 delivered the water to eighteen reservoirs located on the high ridge traversing Delhi from north to south. Water was delivered to consumers only from these reservoirs and not directly from the lines feeding the reservoirs.

From distribution records it is believed that the plant was treating 42 mgd during November 1955. Except for the chlorination facilities, this plant would not have been considered overloaded by American standards.

The Chandrawal No. 2 water treatment plant, located $\frac{3}{8}$ mi closer to Wazirabad, was placed in service in 1953. Raw water was taken from the same aqueducts that serve Chandrawal No. 1. Alum feeding equipment was similar to that at Chandrawal No. 1.

Mechanical flocculators provided in two rectangular tanks, each 19×38×16 ft deep, were equipped with vertical shaft paddles, turned at 3 rpm. At 18 mgd the detention time in these units was 20 min.

Flocculated water was discharged through large rectangular ports to the two circular, mechanically cleaned settling basins. Flocculated water entered the tank tangentially near the bottom of the periphery and was removed from the top near the same point it entered. The basins were 110 ft in diameter and 16 ft deep. At 18 mgd the surface loading rate, a theoretical detention period, and weir loading were 960 gpd/ft, 3 hr, and 0.225 mgd/ft, respectively.

The settled water was filtered in thirteen filters of the same design and size as the last ten filters at Chandrawal No. 1. Filter rates were established by the designers at 1.6 gpm/sq ft. The filter sand had an effective size of 0.5 mm and a uniformity coefficient of 1.58.

Postchlorination and ammonia dosing machinery was of the same design as that provided for Chandrawal No. 1. The chlorine feeding capacity at 18 mgd was 0.64 ppm.

The Okhla water treatment plant is located 16 mi downstream from the Wazirabad pumping station. The machine provided at its prechlorination station was capable of delivering as much as 300 lb/day of chlorine to 2 mgd, or 18.0 ppm. Postchlorination facilities could add an additional 24 lb/day of chlorine. No ammonia was used at this plant.

TABLE 4

Chloride Content of Raw Water and Chemical Dosage at Chandrawal Treatment Plants, November 1955

Day of Month	Chlorides *ppm*	Alum Dose *ppm*	Chlorine Dose *ppm*	Combined Chlorine Residual *ppm*
1–10	5.5–5.7	6.4	0.5	0.25
11	12.7	8.1	0.5	0.2
12	25	41	0.63	0.2
13	60	47	1.2	0.8
14	80	44	1.9	0.7
15	90	44	1.8	0.7
16	61	52	2.6	0.7
17	6.6	43	1.4	0.45
18	6.6	14	0.6	0.3
19–30	6.8–7.0	7.0–8.5	0.5	0.2–0.3

The water was flocculated and settled in two circular upflow basins. These basins were truncated cones with top diameters of 40 ft and with bottom diameters of 36 ft. The basins were approximately 12 ft deep. Settled solids were continually removed by water flowing through 2-in. pipes evenly spaced around the bottom periphery of the tanks.

Six rapid sand filters, each 14×12.5 ft, were installed. Both water and compressed air were used for cleaning the filters. No loss-of-head gages were provided. Filtration rates were fixed and controlled by float valves.

During the first 2 weeks of November 1955, the average prechlorination dosage was approximately 3.2 ppm and the postchlorination dosage varied from 0.3 to 0.5 ppm.

Analyses

Prior to 1956, the chemical analyses for all three treatment plants were determined in a laboratory at Chandrawal No. 1, where daily water examinations were made except on Sundays and holidays. Routine chemical and physical tests were limited to alkalinity, pH, soap hardness, albuminoid nitrogen, turbidity, chlorides, oxygen consumed, and combined residual chlorine. Chlorine residuals were also measured at each plant by means of orthotolidine comparators. No effort was made to distinguish between free and combined chlorine.

Bacteriological examinations of the finished water and of water at the elevated storage reservoirs were made daily by the Delhi State Health Services Laboratory, except on Sundays and holidays. Plate counts were made and MPN's were determined for coliform bacteria by use of MacConkey's medium. Unfortunately, no record is available of the bacteriological quality of the raw water prior to 1957. A bacteriological laboratory was installed at Chandrawal No. 2 in 1957.

Pollution During November 1955

Following floods in October 1955, the Jumna River receded, and it was difficult to maintain a channel to the Wazirabad water intake. Sewage from the Najafgarh Nallah was greater than in previous years.

Construction of a dike between the *nallah* and the intakes during falling river stages was difficult because of the lack of any exposed sand bar or ground to which an obstruction could be anchored. By Nov. 16, the river had fallen enough to permit completion of a dike, but this time the damage had been done.

The chloride content of the raw water provided an indication of the degree of pollution by sewage from the *nallah*, Table 4 gives data from the plant records for November 1955.

The chloride content of the sewage in the *nallah* was measured later and found to be 160 ppm. As this was the only source from which the chloride increase could come, the raw water might have been as much as 50 per cent *nallah* sewage on Nov. 14–15.

The heavy pollution necessitated increases in the coagulant dose to maintain good clarification. Chlorine feed was also increased. Table 4 contains figures from plant records on the chloride content of the raw-water, alum dosage, chlorine feed, and chlorine residuals.

Chlorine Residuals

The chlorine residuals were necessarily combined residuals. The records do not show how long these residuals persisted. Chlorine residual measurements were normally made at the high-lift pumps and there would have been a nominal retention time of about 2 hr in the clear well between the point of chlorine addition and the pumps. Additional contact time was provided between the pumping station and the elevated reservoirs, as all service was

provided from these tanks. No data are available on the chlorine residuals at the elevated tanks between Nov. 11, when two samples showed an average of 0.15 ppm, and Nov. 17, when three samples averaged 0.2 ppm of residual chlorine. It should be pointed out that, because the chlorine dosage during Nov. 13–17 exceeded the installed chlorine-feeding capacity, part of the chlorine was added to the water directly as chlorine gas and was probably only partially absorbed.

Bacteriologic Quality

The only information available on the bacteriologic quality of the finished water is contained in the official report:

> There was a suspicion of some contamination of water in samples taken on Nov. 11, indicated by five or six lactose fermenters (coliform organisms, indicating fecal contamination), but, as the control also showed similar coliform organisms, the laboratory rightly considered that the technique of analysis was defective, probably on account of something['s] going wrong with the media used. Further samples from the same places were taken on Nov. 14, but they showed no evidence of contamination. Altogether it may be stated that, throughout the months of November, December, and January, the bacteriological analysis does not show any evidence of contamination and the standards of bacteriological purity laid down, that *B. coli* organisms should not exceed 2 per 100 cc, in filtered water, were fully complied with during this period.

There is no information on the bacteriologic quality of the water during Nov. 11–13, when pollution from the *nallah* was increasing steadily. The lack of an outbreak of typhoid or dysentery following this heavy pollution is presumptive evidence that treatment at the Chandrawal plants was effective in reducing bacterial concentrations to safe levels. In view of the high endemic rates of typhoid and dysentery, as shown in Table 2, it is inconceivable that the causative organisms of these diseases were not present in the raw water during the period of heavy pollution.

Throughout the period of heavy pollution, water of satisfactory clarity was produced. Taste and odor were, however, reported as being objectionable.

As was pointed out earlier, the incidence of infectious hepatitis or other enteric disease in the population served by the Okhla water plant remained at normal levels. This intake is downstream from not only the Najafgerh Nallah but also from the Barapura Nallah, which receives considerable sewage. In 1955, wastes from about one-third of the population of Delhi entered the river above the Okhla intake.

It is not possible to compare the quality of the water at the Okhla intake with that which reached the Chandrawal plants during the November 1955 emergency. A large but undetermined quantity of dilution water enters the Jumna River between the Wazirabad intakes and the Okhla intake. Flow patterns and water quality at the Okhla intake were further influenced by operation of the gates of a nearby irrigation canal. Large amounts of infectious hepatitis virus must, however, have reached the Okhla plant—particularly during the epidemic, when the Delhi sewage must have contained thousands of times as much virus as was present in the Najafgarh Nallah.

Free residual chlorination, as practiced at Okhla, was probably adequate

to inactivate the virus of infectious hepatitis, whereas the combined chlorine at the Chandrawal plants was not. It is quite possible that the infections were caused largely by water treated prior to Nov. 13, before chlorine doses and residuals were increased markedly. This outbreak does not provide unequivocal evidence as to the viricidal effectiveness of combined chlorine.

Administrative Difficulties

Some of the difficulties at Delhi during the November 1955 emergency were due to administrative difficulties. The state of Delhi, similar to the District of Columbia, was under direct control of the central government and administered through the home office. The engineer-secretary of the joint water and sewage board exercised complete technical and administrative control over water utility facilities and personnel. The ministry of health of the central government and the director of health services of Delhi acted in only advisory capacities on matters related to health.

The general manager of the Delhi water treatment plants and pumping stations had a B.S. degree in electrical and mechanical engineering. His duties consisted mainly of keeping administrative and operation records as well as supervising the repair and maintenance of electrical and mechanical equipment.

The treatment plants were under the direction of a senior water analyst, with an assistant chemist at Chandrawal No. 2 and a man with a subprofessional mechanical engineering degree at Okhla as plant supervisors. A majority of the plant personnel had neither formal training as water plant operators nor the equivalent of a high school education. Salaries were low, and no formal training program for plant personnel was in effect.

Communication between the various levels and groups was not always good. Bacteriological results from the health department laboratory were reported to the water utility officials only if adverse, and the health department received no reports of chemical analyses by the water plant analysts. In general, little use seems to have been made of laboratory findings in the control of plant operations.

Although in charge of all the water and sewage works, the engineer-secretary lacked authority and means to deal effectively with the hepatitis epidemic. Almost 2 weeks were lost before assistance could be obtained from other agencies.

Changes Since 1955

Delhi is a rapidly growing metropolitan area, and a number of changes and improvements have been made in the water system since 1955. These have included expansion of the Chandrawal No. 2 plant from 21.6 to 66 mgd and of the Okhla plant to 7.8 mgd, provision of additional elevated storage and distribution lines, diversion of Najafgarh Nallah 2,000 ft further downstream, primary treatment and broad irrigation of 12 mgd of Nallah sewage, and interception of a large part of the sewage entering the river above the Okhla intake.

Changes in operating procedures and methods which will increase the safety of the supply include provision of prechlorination at both of the Chandrawal plants, discontinuance of the practice of adding ammonia, provision of chemical and bacteriological laboratory facilities at Chandrawal No. 2 plant, inauguration of training programs for plant personnel, and gener-

ally greater concern with problems of water quality.

Conclusions

The epidemic of infectious hepatitis in Delhi in 1955–56 was caused by a combination of unfortunate circumstances. The receding floods in the Jumna River permitted heavy contamination of the raw water at the Chandrawal water treatment plants. At its worst the raw water may have contained as much as 50 per cent sewage.

The high endemic rate of infectious hepatitis (approximately 20 times as great as in the United States) provided a reservoir of infectious hepatitis virus of relatively high titer in sewage.

Although the Chandrawal treatment plants had some deficiencies in design, they were able to produce well clarified water which was evidently bacteriologically safe, as there was no reported increase in typhoid and dysentery above the high endemic levels following the heavy pollution. Disinfection with low combined chlorine residuals was, however, evidently inadequate to protect against the infectious-hepatitis virus.

The Okhla treatment plant, which also treated water containing abnormally high concentrations of infectious hepatitis virus, seems to have been able to produce safe water. This plant, unlike those at Chandrawal, used prechlorination to produce free chlorine residuals of 0.7 ppm.

Although it is not possible to equate the degree of pollution at the Okhla plant with that at the Chandrawal plants, it seems probable that the lack of adequate chlorination capacity and the dependence on combined chlorine residuals for disinfection at the Chandrawal plants were major factors in the epidemic.

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Discussion

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The article by J. M. Dennis is an authoritative and detailed exposition of the known, or disclosed, features of what was perhaps the greatest epidemic of waterborne infectious hepatitis in recorded history. The epidemic has been thoroughly explored, within the limitations of available local reports on both the disease and the characteristics of the raw and finished waters.

Definitive as the reports of Dennis and others in India and the United States are, they leave a number of questions unanswered, perhaps forever. To the water supply profession, the major significance of the Delhi epidemic is, of course, that it was possible for it to occur in the second half of the Twentieth Century. Of equal

importance is the fact that the 1955–56 conditions apparently recurred in 1958. A major rise of disease was avoided by the discontinuation of supply to the consumers during the hazardous period.

Behind the more obvious features of the earlier epidemic, however, lie the unanswered questions of the maximum significance to the health officer, the water utility manager, and the public. The history and the epidemiology of the Delhi epidemic should provide the lessons, which, once learned, will help to prevent its repetition in India and elsewhere. Some of these lessons, both established and controversial, are briefly discussed below.

Lack of Communication

Both within the water supply agency and between that agency and the health department, lines of communication were either nonexistent or less than smooth. Some interdepartmental relations were scarcely friendly. When one considers that several distinct administrative units were responsible for the production of safe water, each essential to successful functioning, but each out of close contact with the others, it is surprising that the disaster was so long in coming.

The resolution of these administrative competitions is now presumably well underway in India. This is not an inappropriate time, however, to reflect upon similar, though latent, situations at home. It may be well to take stock of conditions in the United States, where the long absence of waterborne disease may lull many a water producer into a state of lethargy. Already there are signs that water analyses are becoming so routine that even their scrutiny, either by the water or the health department, is less than careful. The mere accumulation of analytical data, without review and action, sometimes becomes an end in itself, rather than an effective means of control.

Efficiency of Treatment

It has been suggested that the Delhi epidemic may be a demonstration of the breakdown of orthodox treatment processes. The evidence for this highly important conclusion is still far from conclusive—for several reasons:

1. Many reviewers of the Delhi epidemic, including Dennis, suggested that the routine treatment processes, stepped up during the pollution of the raw water, produced water of an acceptable bacterial quality during the critical weeks. Since the early reports of the epidemic, however, the writer has made strenuous efforts, by personal communication with health authorities in India, to obtain an *actual record* of the bacterial quality. So far, no quantitative bacteriological data are at hand to justify the often repeated contention that all was well as far as coliform-organism densities in the final product were considered. The evidence is either nonexistent or has still not been released 2 years after the event.

2. In a well run water treatment plant, the appearance of raw water that is demonstrably half raw sewage would make necessary far greater chlorine and alum dosages than were applied at Delhi even toward the end of the pollution period. The increases in applied chlorine were delayed, slow, and inadequate.

It is presumed that there was no increase in typhoid fever and the dysenteries. This situation, if true, would

suggest that the treatment processes were adequate to prevent the *other* enteric diseases, but inadequate for infectious hepatitis. A much more intensive analysis of the disease situation remains to be made before this conclusion is confirmed. Typhoid fever and dysentery cases occur in Delhi by the thousands each month. Reports are still less than complete, and any major increase may or may not be discernible once all the facts are known.

Treatment and Hepatitis Virus

The important scientific question as to whether the hepatitis virus escapes both filtration and adequate chlorine application in a water heavily polluted with sewage remains quite unanswered.

Undoubtedly, this epidemic will give a much needed dramatic fillip to prompt and extensive research on the effect of water treatment on viruses. Well controlled, laboratory studies of the effect of chlorine on poliomyelitis virus have pointed to conclusions, at the moment, quite at variance with those suggested by the Delhi reports.

It is of interest to recall in this connection that in the earlier waterborne epidemics in the United States, such as in Detroit, Minneapolis, and Rochester, N.Y., thousands of dysenteries occurred with virtually no typhoid. In Delhi, the absence of both of these groups of diseases, if true, adds another mystery for the epidemiologist and the laboratory investigator to solve.

Conclusions

From the standpoint of the water supply profession at large, the Delhi epidemic simply adds another to the long list of severe waterborne epidemics. Each of them, though leaving many scientific questions unanswered, has shown that apathetic control, lack of hour-to-hour alertness, administrative jealousy and competition, and failure to adjust promptly to catastrophic conditions are ever-present dangers to the public health.

Enteric Viruses in Water

Norman A. Clarke and Shih Lu Chang

A contribution to the Journal by Norman A. Clarke, Sr. Scientist, and Shih Lu Chang, Medical Dir., both of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

IN their discussion of the paper of Maxcy and Howe (*1*) on the significance of finding poliovirus in sewage, Ridenour and Miller (*2*) made a statement: to the effect that, although it is not the intention of the public health engineering profession to create public alarm over the possibility of waterborne and sewage-borne polio, the profession would be failing to recognize its responsibilities if it did not attempt to ascertain definitely whether virus disease might be so transmitted. Since that statement was published, 15 years have elapsed, and during the interim only one outbreak of poliomyelitis in the United States (*3*) and one outbreak in Canada (*4*) have been attributed to contaminated water. During the same period, however, infections hepatitis has been established as a waterborne virus disease, and more than 70 newly discovered viruses have been added to the original list of enteric viruses known to be present in the feces of man. Because of the recent outbreak of waterborne infectious hepatitis in New Delhi, India (*5*), and the recognition of the many new enteric viruses, it appears timely to review and record the present status of knowledge regarding the relationship of water to human virus diseases. This review will consider two main points: [1] the epidemiological implications of water supplies in the transmission of virus diseases, and [2] the adequacy of current water treatment methods in removing or destroying viruses in water.

Enteric Viruses

The term "enteric virus," as used in this article, includes all human viruses which are found in quantity in human feces and in sewage. As a matter of convenience, the enteric virus group can be divided into five major subgroups, as shown in Table 1. All enteric viruses share a number of common characteristics:

1. They are excreted in feces in large numbers. Poliovirus, for example, has been reported in concentrations as high as 100,000 virus units per gram of feces (*6*).
2. They can be found in urban sewage, particularly during the late summer and early fall.
3. Infection with many of these viruses is widespread in the normal population; infection rates are highest in infants and young children.
4. Illness, when it occurs with infection with one of these viruses, may be so mild as to be mistaken for a slight cold or, in rare cases, may be as severe as paralytic poliomyelitis.

Proved waterborne outbreaks of enteric-virus disease have occurred only with the virus of infectious hepa-

titis; although outbreaks of poliomyelitis suspected of being waterborne have also been reported (*3, 4*), the evidence incriminating water supplies has been only circumstantial. There are no reports of waterborne outbreaks of diseases caused by Coxsackie, Adeno-, or Echo viruses. This may, however, be the result of the general lack of information on the clinical illness that many of these viruses produce. It may also be a manifestation of the fact that of the known clinical illnesses produced by infection with these viruses, some illnesses are mild enough to be nonreportable, and—perhaps even more important—are accepted as mild and inevitable by many victims and therefore not brought to the attention of the family physician.

Poliomyelitis

Kling (*7*) proposed his *theorie hydrique,* or theory of the waterborne transmission of poliomyelitis, in 1929. The concept did not gain much support until the late 1930's and early 1940's, when poliovirus was discovered in the feces of ill persons, in apparently normal healthy individuals (*8–13*), and in urban sewage (*14–18*). Kling's subsequent isolation of poliovirus from well water in 1939–40 (*19*) attracted little attention, probably because of the unusual circumstances under which the virus was found—that is, on the day following the recognition of a clinical case of poliomyelitis in a member of the family using the well. The only reference made to waterborne poliomyelitis in the United States at that time was that of Paul and Trask (*20*). The frequent isolation of poliovirus from sewage discharged into the Naugatuck River (Connecticut) and the appearance of poliomyelitis cases downstream along the watercourse led these workers to suspect that a heavily polluted river was one of the many channels through which poliomyelitis may be spread in a community.

Maxcy and Howe (*1*) pointed out that, from an epidemiological viewpoint, poliomyelitis did not behave like a waterborne disease, in that its incidence had not been correlated with poor drinking-water supplies, nor had explosive outbreaks of widely scattered cases occurred in cities with municipal water supplies. A recent report of an explosive outbreak of poliomyelitis in Canada (*4*), however, had both of the characteristics that Maxcy and Howe required of waterborne disease. The outbreak occurred in the city of Edmonton, Alta., in 1953 and was reasonably correlated in time with pollution of the Saskatchewan River—its source of supply—by failure of the sewage treatment facilities at a town upstream. Another explosive outbreak of poliomyelitis (*3*) occurred in 1952 in Nebraska, and epidemiological investigation provided evidence that sewage contamination of the water distribution system by back siphonage was the probable source of infection. This evidence was somewhat strength-

TABLE 1

Human Enteric Viruses and Diseases

Major Subgroup	No. of Types	Disease
Infectious hepatitis	1 (?)	infectious hepatitis (yellow jaundice)
Coxsackie		
Group A	24	herpangina; aseptic meningitis
Group B	5	pleurodynia; aseptic meningitis
Poliovirus	3	paralytic poliomyelitis; aseptic meningitis
Adenovirus	19	respiratory infection; eye infection
ECHO	24	aseptic meningitis; summer rash; diarrheal disease

ened by the detection of coliform organisms in the tap water of the area in which the epidemic occurred.

Thus, the criteria that have been used to show that poliomyelitis outbreaks can be waterborne have been epidemiological, and the vast majority of poliomyelitis cases do not appear to be related to this method of transmission. This is also true of infectious hepatitis, which is now accepted as a waterborne virus disease under certain conditions. Mass immunization against poliomyelitis has greatly lessened the chances of explosive outbreaks of that disease. Nevertheless, there still remains the possibility that under unusual circumstances, poliomyelitis could break out as a waterborne infection.

Infectious Hepatitis

It is ironic that the only clear and well documented outbreaks of a waterborne virus disease have been of infectious hepatitis. It is the only member of the enteric virus group that has not been grown in the laboratory. This makes it most difficult to determine the efficacy of water treatment processes in removing or destroying the virus in water.

The literature contains seventeen reports of epidemiologically established or suspected waterborne outbreaks of infectious hepatitis, six of which occurred in the United States. These are summarized in Table 2.

Of the six outbreaks that occurred in the United States, the two that occurred in summer camps leave very little doubt that they were waterborne. There is also sufficient epidemiological evidence that the epidemic that occurred in the small town on the Tidal River was waterborne. The evidence that the remaining three epidemics were waterborne is not as strong, but was acceptable in epidemiological terms for incriminating the water supplies as the probable source of infection.

The New Delhi epidemic of infectious hepatitis is perhaps the most oustanding example of a waterborne virus disease. If one accepts the data on coliform organisms reported by the New Delhi water plant, it appears that, under unusual conditions, the current index may be unreliable for judging the adequacy of modern water treatment processes for destroying or removing the virus of infectious hepatitis and perhaps other enteric viruses.

Thus, it is apparent that outbreaks of waterborne infectious hepatitis do appear from time to time, even though in the majority of cases, at least in the United States, the disease is contracted by personal contact. Large outbreaks may occur when there are sanitary defects in water supplies, and the failure to demonstrate the presence of coliform organisms in such water may not necessarily indicate a biologically safe water.

Adenovirus Infection

The adenoviruses, although they usually cause upper respiratory and eye disease, apparently multiply in the intestine of man and can be shown to be present in human feces and sewage. Although no outbreaks of waterborne adenovirus infection have been documented, it is of interest to note that three outbreaks of one of the clinical diseases caused by adenoviruses have been associated with swimming pools (*37–39*). It is impossible to determine whether these outbreaks were the result of virus-contaminated pool water or personal contacts at the pool. As will be indicated later, the relatively high susceptibility of Type 3 adeno-

TABLE 2

Reported Outbreaks of Waterborne Infectious Hepatitis

Year	Place	Total Cases	Water Supply Incriminated	Water Treatment	Evidence of Contamination
			Domestic		
1944	Children's camp near Philadelphia, Pa.	350	driven well contaminated by cesspool 75 ft away	none	bacterial; viral agent demonstrated
1945–46	Small town on Tidal River, Pa.	52	sewage pollution of river water at point of intake	municipal	epidemiological
1952	Mountainous farming area in Pennsylvania	22*	drilled well polluted by cesspool <50 ft away	none	bacterial
1952	Summer camp in Tennessee	102	spring contaminated by sewage from broken sewer	chlorination	bacterial; dye tracing
1956	Two Arctic villages in Alaska	21	various natural waters with fecal contamination	none	coliform organisms in most samples
1956	Daviess County, Ky.	18	wells contaminated by sewage from septic tanks	none	coliform organisms in most samples
			Foreign		
1940	German troop installation in Paris, France	84	distribution system contaminated by sewage from damaged sewers	municipal	epidemiological
1943	Sanatorium in Sweden	178	conduit contaminated by defective drain	none	bacterial
1944–45	Hotel in mountainous region in northern Sweden	34	sewage-contaminated lake water	inadequate	bacterial
1945	American troop encampment in Italy	100	well water with fecal pollution	none	bacterial
1946	American military camp in a German city	31	raw water contaminated by sewage pollution near intake	municipal	bacterial
1947	Two American ordnance units in Germany	26	contaminated stream water intended for industrial use	none	bacterial
1947–48	American military camp in Berlin, Germany	52	distribution system contaminated by sewage	municipal	bacterial
1950	British troop encampment in Hong Kong	81	treated water contaminated by polluted water	municipal	epidemiological
1955–56	New Delhi, India	30,000–50,000	source with heavy fecal contamination	municipal	high Cl^- ion and high Cl_2 and alum demand of water
1956–57	A factory in Kalmer County, Sweden	46	well water contaminated by sewer <50 ft away	none	bacterial
1958	Student picnic in Australia	6	river water contaminated by sewage effluent	none	bacterial

* Nine of these cases were traced to the well water.

virus to chlorine lends support to the contact-infection hypothesis.

Coxsackie and ECHO Viruses

The Coxsackie and enteric, cytopathogenic, human orphan (ECHO) viruses together total 53 recognized types, none of which has ever been associated with waterborne infection. Many data are available on the effects of conventional water treatment processes on certain of these viruses. This apparent incongruity is a reflection of the relative ease with which these viruses can be handled in the laboratory; they have thus been used as convenient laboratory tools. Recently, several of these agents have been recovered from feces of diarrhea cases (*40–42*) and Type 18 ECHO virus has been clearly shown to be related to diarrhea in children (*43*). Because these viruses are chiefly feces borne and are readily isolated from sewage and sewage effluent (*44–50*), they therefore must be considered as potential waterborne viruses.

Other Viruses

Certain viruses—influenza, for example—are occasionally isolated from feces, but it is believed their presence results from swallowing of the discharge from the upper respiratory areas where the virus is normally shed. Recently a virus designated salivary gland virus (SGV) has been isolated from the urine of healthy children (*51, 52*). This virus should be present in sewage or sewage effluent, but, as most SGV infections occur in early childhood through personal contact, the

TABLE 3

Reduction of Coxsackie, Polio, Theiler's, and Infectious Hepatitis Virus in Water on Storage

Type of Water	Virus	Probable Storage Necessary for 99 Per Cent Reduction—*days*		
		8°–10°C	20°–23°C	30°C
River water, some or moderate pollution	Coxsackie A2 (*53*)	14	5	
	Theiler (*54*)	56	18	9
River water with gross pollution	Coxsackie A2 (*53*)		47	
River water with added feces (1 : 200)	poliovirus (*55*)	*		
Autoclaved river water	Coxsackie A2 (*53*)	160	102	
Distilled, tap, or spring	Coxsackie A2 (*53*)	>272	100	
	Coxsackie A5 (*57*)	280	210†	
	Theiler (*54*)	>315	132	21
	poliovirus (*57*)	>100		
Contaminated well water	Infectious hepatitis (*21*)		‡	

* Virus present after 188 days' storage.
† Storage at 20°–30°C.
‡ Produced illness in volunteers after 10 weeks' storage.

presence of this virus in urine has very little significance in connection with water supplies.

The information on the effectiveness of various water treatment processes in removing or inactivating viruses is very incomplete, and many of the early studies are difficult to interpret in light of subsequent developments. A small quantity of information data has been accumulated in recent years upon which fair judgments may be based.

Storage

The simplicity, convenience, and economy of water storage for reducing the number of infectious agents in water suggest it as the ideal method of treatment, provided the supply system permits sufficiently long detention periods. The effectiveness of this method in reducing viruses in water has been examined with Coxsackie virus, Theiler's virus, poliovirus and the virus of infectious hepatitis (*21, 53–57*). These data are summarized in Table 3.

In general it appears that virus survival is longer in treated or clean water than it is in moderately polluted water. On the other hand, virus survival seems to be longer in grossly polluted water

TABLE 4

Reduction of Human Enteric Viruses in Water by Chemical Flocculation

Virus	Type of Water	Flocculation Process		Floc Amount or Description	Virus Removal
		Stages	Coagulant Added* *ppm*		
polio (*56*)	tap	1	100		little†
	raw	1	100		some‡
polio (*60*)	river	1	136		some to significant§
		1	410		some
		1	136–273	0.4–1.03 ml/l	little to some
		1	273–546	1.5–2.2 ml/l	significant
Infectious hepatitis‖ (*61*)	distilled	1	69		little to some
Coxsackie A5 (*57*)	spring	1	28–45		some
Coxsackie A2 (purified) (*62*)	Ohio River (16–255 ppm turbidity)	1	15	good	95.7 per cent at 25°C
		1	25	very good	95.9 per cent at 5°C
		2	15	very good	98.6 per cent at 25°C
			15*	very good	99.8 per cent at 25°C
		2	25	very good	99.6 per cent at 5°C
			25*	very good	99.9 per cent at 25°C

* Alum except where marked with an asterisk; asterisks indicate ferric chloride.
† Probably less than 25 per cent.
‡ Probably less than 50 per cent.
§ More than 50 per cent.
‖ Gauze-strained fecal suspension in distilled water.

than in moderately polluted water. The limited data available are insufficient to allow a generalized statement on the effectiveness of storage in reducing enteric viruses in natural surface waters. It is apparent, however, that in relatively clean waters or water devoid of the microscopic flora or fauna that are normally present in surface waters, survival times of enteric viruses are so prolonged that the use of storage alone is impractical as a means of eliminating viruses.

The presence of infectious hepatitis virus in human volunteers who ingested contaminated well water stored 6 weeks in the well and 4 weeks in the laboratory (*21*) indicates that this is also a hardy virus, capable of at least 10 weeks' survival in relatively clean water.

Flocculation

The removal of viruses from water by chemical flocculation appears to be the result of a metal cation–protein reaction in which a metal-virus complex is formed and aggregates to form a precipitate (*58, 59*). The reaction is therefore nonspecific and the results obtained with one animal virus should be applicable to other animal viruses. On the other hand, the degree of virus removal depends entirely on the efficiency of the flocculation process.

The pertinent information available on this subject is summarized in Table 4. It is apparent that there is wide variation in virus removal efficiency of the flocculation process as studied by several workers (*56–62*). It is of interest that the high virus removal attained by Chang and others (*58, 59, 62*) was achieved with low dosages of aluminum sulfate, whereas low efficiency was attained by others who used high dosages. This clearly indicates that dosage of flocculant alone is not a measure of the efficiency of the process. A critical comparison of the virus removal efficiencies of flocculation processes cannot be made unless one knows the conditions under which the processes are employed. As most investigators have not indicated the relative performance of the flocculation process as judged by visual inspection of turbidity removal, the relatively low virus removals reported might suggest that the flocculation process was inadequate.

Results of a recent study (*62*) indicate that if the flocculation process is satisfactorily applied, more than 95 per cent removal of added virus should be obtained with 15–25 ppm of alum or ferric chloride in moderately polluted water having a turbidity of less than 260 ppm. In double-stage flocculation, with the same dosage of flocculants, more than 99 per cent removal should be expected. The percentage removal may be slightly lower in the cold than in the warm months. These experiments also showed that virus removal roughly parallels the removal of coliform, total bacteria, and turbidity. It is worth noting that virus is not destroyed by the flocculant but merely concentrated in the floc (*58–60*). The flocculation process has been applied by Stevenson and associates (*63*) for purifying virus suspensions.

Activated-Carbon Adsorption

Carlson and others (*56*) reported a partial removal of poliovirus from water with 10–50 ppm activated carbon but did not indicate the magnitude of the removal. Neefe and others (*61*) reported the removal of about 40 per cent of infectious hepatitis virus by a combination of flocculation and activated carbon (25 ppm). As floc-

culation is generally more effective than the activated-carbon adsorption, it seems likely that the latter effected a smaller portion of the 40 per cent removal than the former. The observation of Fair, Chang, and Moore (*64*) on Theiler's virus also indicates a low virus removal efficiency for activated carbon. Hence, it appears that activated carbon, at the dosage applied in conventional water treatment, plays an unimportant part in removing virus.

Filtration

Carlson and others (*56*) reported very little removal of poliovirus when a virus-laden water was filtered through a 30-in. column of Ottawa sand in a glass tube of 2½-in. diameter at a rate of 144 ml/min (approximately 0.28 gpm/sq ft), the effective size of the sand being 0.508 mm and uniformity coefficient 1.24. When the sand column was impregnated with enough alum floc to reduce the flow rate from 144 to 102 ml/min, a significant amount of the virus was removed.

Employing a 24-in. column of the same type of sand in a glass tube of 2-in. diameter and using a flow rate of close to 2 gpm/sq ft, Kempf and others (*60*) obtained results with poliovirus very similar to those of Carlson and others. Certain inconsistencies in the results of Kempf, such as the higher recovery of the virus in the filter effluent than in the influent in one test and the reverse in the other, could readily be explained by the very small number of test animals (monkeys) used.

Using a bacterial virus (bacteriophage against *Staphylococcus albus*) as a testing organism, Dieterich (*65*) and Ryckman (*66*) obtained removal data under various testing conditions which indicate that the removal of virus by filtration is an adsorption phenomenon and that sand, being a relatively poor adsorbent, has low removal efficiency, especially when the filtration rate approaches that used in water plant practice (2 gpm/sq ft).

The efficiency of a portable diatomaceous earth filter in removing the virus of infectious hepatitis from water was reported to be very low by Neefe and others (*61*).

It appears, then, that rapid sand filtration is relatively ineffective in removing viruses in water and that the low efficiency can be attributed to the inherently poor adsorption properties of the sand.

Chlorination

Because of the complications created by the chlorine demand of organic matter and the formation of combined-chlorine compounds with nitrogenous substances, data on the destruction of viruses by chlorination are informative only when the chemical conditions in the test water are well defined and the types of titrable chlorine existing in the chlorinated water are differentiated. Furthermore, the destruction of viruses is a rate process, and the rate of destruction under a set of fixed conditions is proportional to the concentration of a particular kind of titrable chlorine, especially free chlorine. In viricidal studies of chlorine, sufficient demand-free virus material should be present to permit the inactivation rate to be ascertained with reliability. Because of requirements stated above as criteria for good data, many reports on the destruction of viruses by chlorine are omitted from this article. For example, all studies prior to 1946

failed to differentiate between free and combined chlorine. Many of the early reports also indicated such a high chlorine demand in the test system that the test water resembled sewage effluent more than natural water, and it is difficult to interpret the information for viricidal efficiency of the chlorination process.

Pertinent data concerning the viricidal efficiency of chlorination in terms of water treatment practice are summarized in Table 5 under two main groups: [1] data on virus destruction by free chlorine in water with a high chlorine demand and [2] data on similar destruction in water with a low chlorine demand or in demand-free water. The former results are informative on the viricidal efficiency of prechlorination, either for residual or superchlorination of raw water, and the latter are useful in judging the viricidal efficiency of chlorine applied to flocculated or filtered water.

In Table 5, irregularities in viricidal efficiency of free chlorine are apparent in some of the reports, and the use of animal inoculations for assaying virus concentrations makes quantification difficult. For these reasons, the free chlorine–contact time combinations shown in the table are quoted because they appear to represent a high rate of virus destruction with some margin of safety.

The viricidal data of Weidenkopf (*74*) are the most quantitatively accurate to date, because the test conditions were well defined and the technique used for estimating virus concentrations (the plaque count method) provides an accurate determination. It is of interest that Weidenkopf's results indicate a first-order reaction in the destruction at pH 8.5 by free-chlorine concentrations ranging from 0.2 to 5.0 ppm; whereas at pH 6.0 and 7.0, the first order reaction was observed only at relatively high concentrations of free chlorine. As the chlorine concentration was lowered to less than 0.23 ppm, the survival curves assumed more of a retardant die-away shape. Weidenkopf stated that the purified virus suspension used in his study did not exhibit a significant chlorine demand during the course of his experiments. It can be reasonably assumed, however, that there was some slight loss of free chlorine during the test periods, particularly during relatively long exposure periods. If the retardant, die-away type of survival is attributed to the difference in resistance of the virus particles themselves, it should also have occurred at pH 8.5 as well as the lower pH values. A more logical explanation of the phenomenon may be that the very slight free-chlorine loss during his experiments did not measurably influence the death rates with high residuals, but became measurably significant as the residuals were lowered and approached 0.04 ppm, at which concentration long exposure times were necessary to achieve good virus kills. This would be particularly noticeable at low pH values, when a greater portion of the free chlorine is in the much more active HOCl form.

On the basis of the foregoing consideration, it seems likely that in selecting the free chlorine-contact time combination for a 99 per cent or greater destruction for the retardant die-away inactivation curve, a wider margin of safety is provided and a more representative picture of the true inactivation curve is obtained if one actually uses the point on an experimental

TABLE 5

Viricidal Efficiency of Free Chlorine in Water

Nature of Virus-Laden Water	Temperature °C	Final pH	Free Chlorine—*ppm*		Viricidal Results
			Initial	Residual*	
High Chlorine Demand					
Partially purified polio in distilled water	room	<7.2	15.0	0.25–0.6	10-min chlorine contact protected all 16 inoculated mice
	room	<7.2	7.0–10.0	0.1–0.25	30-min chlorine contact protected all 16 inoculated mice
Partially purified polio II in distilled water	21–25	7.0–7.4	4.5–9.0	0.0–0.15	30-min chlorine contact protected all 52 inoculated mice
Partially purified polio II in distilled water	21–25	7.0–7.4	2.5–7.0	0.15–0.75	10-min chlorine contact protected all 35 inoculated mice
Partially purified polio II in lake, river, and well water	19–25	7.4–7.9	2.2–4.0	trace–0.05	10-min chlorine contact protected all 75 inoculated mice
	19–25	7.8–8.3	3.0–5.0	trace–0.05	10-min chlorine content protected 124 or 127 inoculated mice
	21–26	8.0–11.0	6.0	0.0	30-min chlorine contact protected all 33 inoculated mice
Partially purified Theiler's virus in tap water	25–27	6.5–7.0	4.0–6.0	0.18–0.24	98.6 per cent destruction in 10 min
	25–27	6.5–7.0	4.0–6.0	0.66	99 per cent destruction in 5 min
Feces-borne infectious hepatitis virus in distilled water	room	6.7–6.8	3.25	0.4	30-min chlorine contact protected all 12 volunteers
Low or No Chlorine Demand					
Purified polio II in distilled and lake water	19–25	7.4–7.9	1.0–1.5	0.05–0.2	10-min contact protected all 164 inoculated mice
Purified Coxsackie A2 in demand-free water	3–6	6.9–7.1	0.58–0.62		99.6 per cent destruction in 10 min
	3–6	6.8–7.1	1.9–2.2		99.6 per cent destruction in 4 min
	3–6	6.9–7.1	3.8–4.2		99.6 per cent destruction in 2½ min
	3–6	8.8–9.0	1.9–2.0		99.6 per cent destruction in 24 min

* Blanks in this column indicate no essential change from the initial free-chlorine concentration; the virus exhibited no demonstrable chlorine demand.

TABLE 5—*Viricidal Efficiency of Free Chlorine in Water (contd.)*

Nature of Virus-Laden Water	Temperature °C	Final pH	Free Chlorine—ppm		Viricidal Results
			Initial	Residual*	
Low or No Chlorine Demand (*contd.*)					
Purified Coxsackie A2 in demand-free water (*contd.*)	3–6	8.8–9.0	3.7–4.3		99.6 per cent destruction in 9 min
	3–6	8.8–9.0	7.4–8.3		99.6 per cent destruction in 5 min
	27–29	6.9–7.1	0.16–0.18		99.6 per cent destruction in 4 min
	27–29	6.9–7.1	0.44–0.58		99.6 per cent destruction in 3 min
	27–29	8.8–9.0	0.10–0.18		99.6 per cent destruction in 10 min
	27–29	8.8–9.0	0.27–0.32		99.6 per cent destruction in 7 min
	27–29	8.8–9.0	0.92–1.00		99.6 per cent destruction in 3 min
Purified polio I (Mahoney strain) in demand-free water	0	6.0	†	0.39	99.6 per cent destruction in 3½ min
	0	6.0	†	0.80	99.6 per cent destruction in 1½ min
	0	7.0	†	0.23	99.6 per cent destruction in 8 min
	0	7.0	†	0.53	99.6 per cent destruction in 4¼ min
	0	8.5	†	0.53	99.6 per cent destruction in 16 min
	0	8.5	†	1.95	99.6 per cent destruction in 7½ min
	0	8.5	†	5.00	99.6 per cent destruction in 3 min
Purified polio I (Mahoney strain) in demand-free water	25–28	7.0	0.21–0.30		99.9 per cent or greater destruction in 3 min
	25–28	9.0	0.21–0.30		99.9 per cent or greater destruction in 8 min
Purified polio III (Sankett strain) in demand-free water	25–28	7.0	0.11–0.20		99.9 per cent or greater destruction in 2 min
	25–28	9.0	0.11–0.20		99.9 per cent or greater destruction in 16 min
Purified Coxsackie B5 in demand-free water	25–28	7.0	0.21–0.30		99.9 per cent or greater destruction in 1 min
	25–28	9.0	0.21–0.30		99.9 per cent or greater destruction in 8 min
	1–5	7.0	0.21–0.30		99.9 per cent or greater destruction in 16 min
	1–5	8.0	0.21–0.30		99.9 per cent or greater destruction in 30 min
Purified adenovirus 3 in demand-free water	25	8.8–9.0	0.20		99.8 per cent destruction in 40–50 sec
	25	6.9–7.1	0.20		99.8 per cent destruction in 8–16 sec
	4	8.8–9.0	0.20		99.8 per cent destruction in 80–110 sec
	4	6.9–7.1	0.20		99.8 per cent destruction in 8–10 sec

† Data were not given.

curve rather than computing it from the average of the slope of all straight-line sections of the curve. Thus, for the purpose of comparing the resistance of poliovirus Type 1 (*74*) and Coxsackie A2 virus (*73*), the contact times required for a 99.6 per cent destruction of poliovirus Type 1 were so obtained from Fig. 1–3 of Weidenkopf's report and presented in Table 5.

The information in Table 5 reveals several points of significance. First, there is a definite indication that Theiler's virus is more resistant to free chlorine than the Coxsackie A2 virus, which, in turn, is more resistant than the poliovirus Type 1. The relative resistance of the virus of infectious hepatitis to free chlorine cannot be stated, as contact times of less than 30 min were not tested. Adenovirus Type 3 has about the same resistance to free chlorine as do *Esch. coli* cells. It thus becomes apparent that different viruses exhibit a wide variance of their susceptibility to chlorine.

Second, there is a profound pH effect on the viricidal efficiency of free chlorine. The data of Weidenkopf shows that lowering the pH from 7.0 to 6.0 reduces the inactivation time by approximately 50 per cent, and the results of both Weidenkopf and Clarke indicate that a rise in pH from 7.0 to 8.3–8.9 increases the inactivation time by a factor of six.

Third, the results of Clarke suggest that the temperature coefficient for a 10-deg change (Q_{10}) in the destruction of virus by free chlorine lies in the range of 2.0 to 3.0, indicating that lowering the temperature by 10°C increases the inactivation time by a factor of 2–3.

Fourth, the data of both Weidenkopf and Clarke on the free chlorine–contact time relationship indicate, as a whole, that the value of N, the chlorine concentration coefficient, lies in the range 0.7–0.9. This means that a doubling of the free-chlorine concentration reduces the inactivation time by a little less than half. Therefore, there is a slight advantage in lengthening the contact time to improve virus destruction over increasing the chlorine concentration.

Qualitatively, the results of Kelly and Sanderson (*67*) also are in agreement with the four points made above in that they observed that the viricidal efficiency of free chlorine was dependent upon pH, chlorine concentration, exposure time and temperature. They also made the important practical point that complete inactivation of certain enteric viruses could not be achieved by the usual conditions for bacterial disinfection of water (0.2 ppm chlorine for 10 min at pH 7.0) at an initial level of 300–3,000 virus doses.

As a whole, the information in Table 5 indicates that, although most viruses examined are unquestionably more resistant to free chlorine than are coliform bacteria, virus destruction is possible by prechlorination practices. In the prechlorination of raw water any of the enteric viruses so far examined would be effectively destroyed by a free chlorine residual of about 1.0 ppm, provided that it could be maintained for about 30 min and that the virus particles were not embedded in particulate organic matter that could serve as a protecting envelope.

The effectiveness of postchlorination practices in destroying enteric viruses is uncertain, because relatively low chlorine residuals are usually maintained. The rate of inactivation of viruses with low chlorine residuals is

markedly affected by temperature, pH, and possible detention times. The data of Table 5 would seem to indicate that if the water temperature were approximately 20°C and the pH were not more than 8.0–8.5, a free chlorine residual of 0.2–0.3 ppm would probably be sufficient to destroy most of the tested viruses in 30 min. At water temperatures below 10–15°C and at a pH of more than 8.5, effective destruction of virus with free chlorine residuals of 0.2–0.3 ppm is probably not feasible unless long detention periods are possible.

Combined Chlorine

Trask and others (*76*) reported that 5.4 and 8.1 ppm of residual chlorine as chlorine-ammonia was required to destroy 90 per cent of Theiler's virus (FA strain) in 30 and 10 min, respectively. The temperature and pH of the treated water were not given, but the chlorine-ammonia weight ratio was 1:4. On the other hand, Chang and others (*54*) found that at 26°C, pH 6.8–7.1, and a chlorine-ammonia weight ratio of 2:3, 5.2 ppm of residual titrable chlorine effected only 85.7 per cent destruction of Theiler's virus in 60 min. Under these conditions, 50 per cent of the titrable chlorine exists as $NHCl_2$ and 50 per cent as NH_2Cl (*77*).

The viricidal efficiency of combined chlorine must be very low, as most investigators who have worked with suspensions of crude or partially purified virus have found that much of the chloride existed as combined forms and that the viricidal efficiency was traceable almost entirely to the free chlorine residuals. It is probable that most combined chlorine consists of organic N-chlor compounds and a small amount exists as chlorine-ammonia. Trask and others (*76*) stated that 12.1 ppm of titrable chlorine as azochloramid destroyed 90 per cent of the Theiler's virus in 30 min, and Fair and others (*64*) showed that 18–20 ppm titrable chlorine as monochloramine-T destroyed 60–80 per cent of the Theiler's virus in 60 min at 27°C and pH 7.0–7.2. Although these data are inadequate for definite conclusions, the low viricidal efficiency of these compounds is clearly demonstrated.

Chlorine Dioxide

The experiments of Ridenour and Ingols (*69*) indicate that chlorine dioxide is as effective as free chlorine in inactivating poliovirus if the residuals are measured by the orthotolidine-arsenite (OTA) method. More recently Hettche and Schulz-Ehlbeck (*78*) reported that 0.08 ppm chlorine dioxide—measured by the orthotolidine (OT) method—had the same viricidal activity on poliovirus as 0.15 ppm ozone or 0.25 ppm free chlorine. Unpublished data obtained by Moore and Post of the Robert A. Taft Sanitary Engineering Center indicate that the OTA method is only qualitative in measuring chlorine dioxide residuals. Quantitative comparison of data on the viricidal efficiency of free chlorine and chlorine dioxide is therefore impossible to evaluate if OT or OTA methods are used to measure chlorine dioxide residuals.

Elemental Iodine

Molecular iodine (I_2) is a convenient and practical disinfectant for emergency treatment of small quantities of drinking water. Recent reports (*79, 80*) indicate that different viruses have different resistances to iodine; for ex-

ample Coxsackie A2 and B1 viruses have essentially the same resistance to molecular iodine, but twice the resistance (in terms of contact time) as poliovirus Type 1 or ECHO 7 viruses, and Coxsackie A9 virus appears to be more resistant than Coxsackie A2 or B1 (*81*). In order to achieve 99.6 per cent destruction of Coxsackie A2 or B1 virus, contact times of 6, 3.5 and 2.25 min at 25°C were required with 5, 10, and 15 ppm of residual iodine.

When the data on Coxsackie B1 virus are compared with those of Clarke (*73*) on Coxsackie A2 virus, it is seen that molecular iodine is much less viricidal than free chlorine, even when the comparison is made on a molar basis. The lower the temperature, the greater is the discrepancy. Nevertheless, the 15-min contact at an iodine residual of about 5 ppm recommended for emergency treatment of water at ordinary temperature should effectively destroy nearly 100 per cent of viruses having a resistance comparable to Coxsackie A2 and B1 virus, but it will kill only about 99 per cent of those viruses that are as resistant as Coxsackie A9 virus.

Ozone

Kessel and others (*82*) report that 0.05–0.45 ppm of residual ozone destroyed the same amount of poliovirus in 2 min as 0.5–1.0 ppm residual gaseous chlorine in 1½–3 hr. No differentiation was made of the types of residual that existed, however, and, as a crude-virus suspension was used in the tests, it is likely that most, if not all, of the residual chlorine was in the combined form. The data of Hettche and Schulz-Ehlbeck (*78*) do indicate that ozone is slightly more viricidal against poliovirus than is free chlorine on a weight basis.

Heat

The literature on thermodestruction of viruses is too voluminous to review in full. There are discrepancies in the thermal death points determined by different workers for even the same virus. The more useful quantitative data on the thermodestruction of enteric viruses in water are those of Melnick and his associates. Working with a mouse-adapted strain of poliovirus, Lawson and Melnick (*83*) showed that 99.9 per cent or greater destruction of the virus was achieved when the water suspension was heated at 60°C for 30 min. In a later report Kaplan and Melnick (*84*) presented data indicating that the poliovirus (feces borne, monkey adapted, or mouse adapted) and Theiler's virus, suspended in water at a concentration of 300 doses per inoculum, were rendered noninfective after heating at 55°C for 15–30 min or at 71.1°C for 7½ sec. In another report (*85*) they showed that several strains of Coxsackie virus (A1, A4, and B1), suspended in water at concentrations of 10^8 to $10^{7.5}$ doses per inoculum, were made noneffective after heating at 55°C for 10–15 min or at 71.1°C for 7½–10 sec. The thermodestruction data of Robinson (*86*) on two strains of Coxsackie B virus were in general agreement with those quoted above; however, Robinson states that a strain (MM) of poliovirus was definitely more resistant, but that most of its infectivity was destroyed by heating at 62°–64°C for 30 min. Thus, the temperatures and contact times used in milk pasteurization appear adequate for destruction of most enteric viruses.

Very little has been reported on thermodestruction of the virus of infectious hepatitis. The only information

is that of Havens (*87*), who showed that heating at 56°C for 30 min failed to render an infectious hepatitis serum noninfective. It should be noted, however, that viruses suspended in proteinaceous fluids are more difficult to destroy by heat than they are in water.

Thus, from the data presented, it appears that disinfectants, such as chlorine-ammonia and N-chlor compounds, have such low viricidal efficiencies that the dosages required for an effective destruction of enteric viruses are too high to be practical in water treatment.

Ozone and chlorine dioxide are probably highly effective in destroying viruses in water. Their viricidal efficiencies as compared to that of free chlorine, however, are yet to be ascertained under well defined test conditions. With the tissue culture method for production of viruses and with the plaque count or MPN (*88*) technique for quantification of viruses, the relative viricidal efficiencies of these three powerful disinfectants at different temperatures and pH levels can be accurately determined.

Elemental iodine and heat are effective viricidal agents in water treatment. but their use is most applicable to small water supplies under emergency conditions.

Summary

A literature survey has been conducted in an attempt to ascertain the role that water supply may play in the transmission of enteric viral infections. Despite the fact that all enteric viruses are feces borne and are sometimes present in sewage and sewage effluent, no enteric-virus disease other than infectious hepatitis has been shown to be waterborne, although a few outbreaks of poliomyelitis are suspect. A list of the enteric viruses and some of the diseases they cause has been presented.

The virus removal and destruction efficiencies of modern water treatment processes have been evaluated in the light of the available information obtained in experimental studies. These data, though extremely limited, indicate the following:

1. Storage of slightly to moderately polluted surface water at temperatures prevailing in warm months can inactivate 99 per cent or more of Coxsackie A2 virus in about a week. The percentage virus reduction is greatly lessened when the temperature is lowered to that prevailing in cold months; when the water is grossly polluted; or when the water is devoid of microbial flora and fauna normally present in surface waters.

2. The flocculation process, when satisfactorily applied using either alum or ferric salt, can remove 95–99 per cent of Coxsackie A2 virus in water in a single-stage flocculation or more than 99 per cent in a double-stage operation. Differences of turbidity of 16–260 ppm and of temperature of 5°–25°C exert an insignificant effect on virus removal. A parallelism exists between the removals of virus, total bacteria, coliform organisms, and turbidity.

3. Activated carbon and sand are not effective media for removing viruses in water; this is probably because of their low virus adsorption capacities.

4. Free chlorine effectively inactivates enteric viruses in water. The residuals required are dependent upon temperature, pH, and contact time. Poliovirus, Coxsackie virus, and the virus of infectious hepatitis appear to

be more resistant to chlorine than are coliform or enteric pathogenic bacteria.

5. Combined chlorine, either as chlorine-ammonia or N-chlor compounds, is far less viricidal than free chlorine.

6. Ozone and chlorine dioxide are probably effective viricidal agents in water treatment, but their efficiency at different temperatures and pH values as compared to that of free chlorine remains to be determined.

7. Heat is effective in destroying viruses in water. Pasteurization processes, such as those applied to milk, should provide a margin of safety in the destruction of enteric viruses.

8. Elemental iodine is effective in destroying viruses in water.

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Simple Automatic pH Control Device for Treatment Plants

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A contribution to the Journal by W. Bruce Murray, Treatment Plant Supt., Water Dept., Long Beach, Calif.

WATER treatment plants usually have to practice some form of pH adjustment on finished water as a means of correcting any corrosive tendency the water may have acquired during treatment. Changes in prechlorination or coagulation dosages or even variations in the raw water itself cause difficulties to operating personnel in maintaining a uniform pH. The device described in this article is an inexpensive controller that anyone with only a moderate knowledge of electronics can assemble; yet its accuracy is such that it will maintain the pH of the finished water within ±0.05 unit of the desired figure.

Principle of Operation

To illustrate the way in which the pH control device functions, one may suppose, for example, that it is desired to maintain a uniform pH in the effluent of a treatment plant where the pH value is normally quite irregular. The flow of the plant effluent, Q, is to be metered by a primary meter that provides an electrical impulse each time 10,000 gal of water has passed (Fig. 1). At a distance S downstream of the point of chemical injection, is a pH-detecting electrode assembly that continuously samples the effluent and furnishes a d-c output to a meter relay in proportion to the instantaneous pH of the effluent. This electric signal is opposed by the output from a bridge circuit, which is set at an electrical value equivalent to the desired pH. At electrical zero (the point of bridge balance), the electrical equivalent of the pH is equal to the bridge output and there is no change in the rate of chemical injection. If there is a gain or loss in the pH of the effluent, the indicating needle on the meter relay deviates from its centered position, closes with the appropriate relay contact, and eventually causes an increase or decrease in the rate of feed. The caustic-soda pump used in this illustration is operated on a time impulse basis—that is, the pump functions just long enough to provide the quantity of caustic soda necessary to dose each 10,000-gal increment of effluent water (indicated by the primary meter) to the desired pH. The meter relay shortens or lengthens the period of pump operation by varying the time constant of the pH control device every time an impulse is received from the primary meter. If the pH of the plant effluent is equal to the desired pH, the meter relay is at balance and the time constant remains unchanged. The pump operates again for the same time interval as during the previous cycle upon receipt of the next 10,000-gal impulse. Thus the automatic pH controller has two important features: proportional control (the frequency of pump operation is directly proportional to the number of impulses received, or

the rate of flow) and floating control (the amount of caustic soda entering the plant effluent per cycle is increased or decreased to correct the pH as long as the latter deviates from the desired value).

Summary of Operation

The following sequence of events takes place in the automatic control of pH:

1. The primary meter initiates a cycle by providing an electric pulse to the pH control device.
2. The caustic-soda pump operates for a period determined by the pH control device and attempts to supply just enough caustic soda to adjust the plant effluent to the proper pH.
3. The pH electrode assembly, located downstream from the point of caustic-soda injection, provides an output signal proportional to instantaneous pH of the plant effluent. If the output is higher than that of the desired pH, the time constant in the pH control device is decreased, thereby shortening the next cycle of operation. If the output is lower than that of the desired pH, the time constant in the pH control device is increased, thus lengthening the next cycle of pump operation. If the output is exactly the same as the desired pH setting, the time constant in the pH control device is left unchanged and the operating time of the caustic-soda pump is left unchanged for the next cycle.

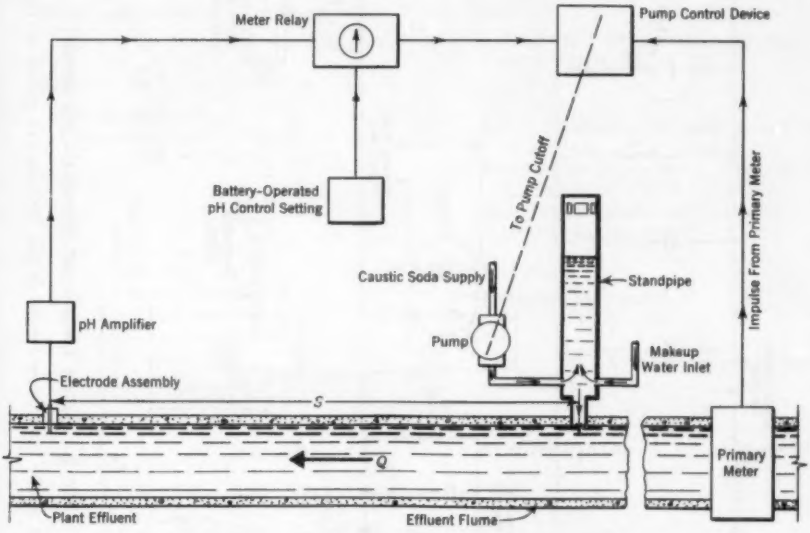

Fig. 1. Flow and Signal Diagram of the Automatic pH Control

The circuitry of the device is shown schematically in Fig. 2.

Circuit Description

The automatic pH control device shown schematically in Fig. 2 is essentially an electromechanical switch; its

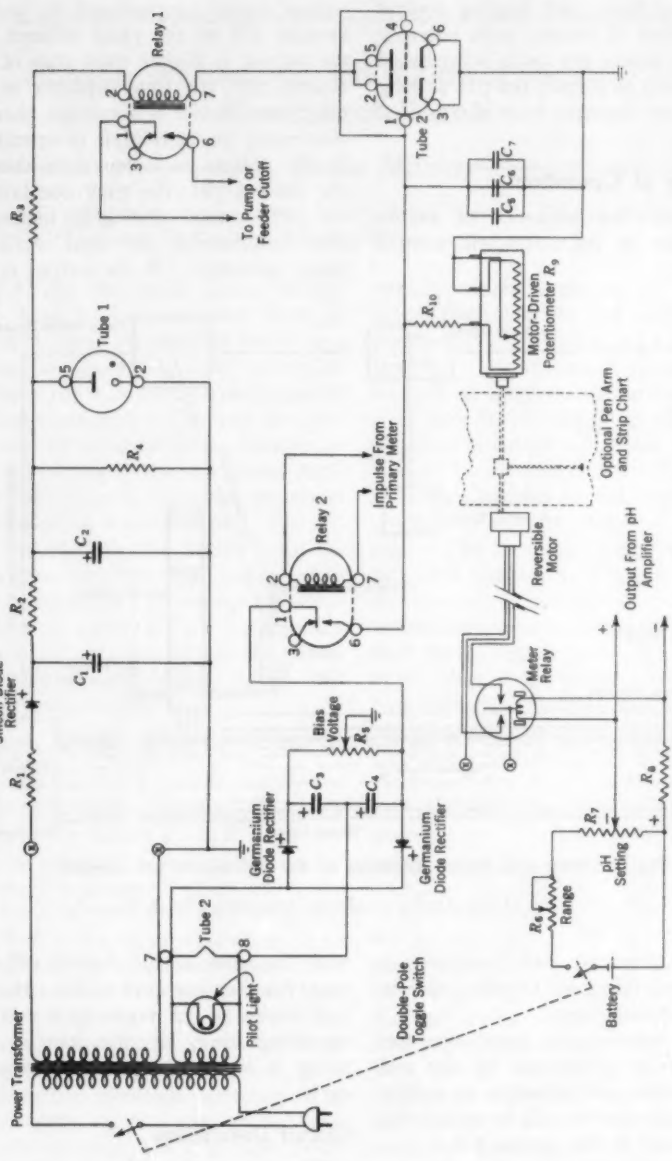

Fig. 2. Circuit Diagram of Automatic pH Control

Details of the components used in the circuits are given in Table 1.

contact time is dependent on the resistance setting of the variable potentiometer R_9 and the three capacitances C_5, C_6, and C_7. The single-pole relay in the plate circuit of Tube 2 controls the "on and off" time of the pump according to the time-limit of the resistance-capacitance (R-C) network on the parallel grids of Tube 2. During normal operation, upon receipt of a 10,000-gal impulse signal from the primary meter, Relay 2 initiates a time cycle on the grids of Tube 2, which activates Relay 1 for a period sufficient to treat the 10,000-gal volume. With zero voltage across the R-C net-

TABLE 1

Materials List for Components of Automatic pH Control

*Power transformer**

125 v, 1 ma, with 6.3-v secondary taps

Rectifiers

Silicon diode, 150 ma
Germanium diode (1N34A)

Resistors

R_1: 22 ohms, 1 w
R_2: 3,300 ohms, 1 w
R_3: 4.700 ohms, 1 w
R_4: 51,000 ohms, 1 w
R_5: 1,000-ohm wire-wound pot
R_6: 5,000-ohm wire-wound pot
R_7: 1,000-ohm wire-wound pot
R_8: 2,200-ohms, ½ w
R_9: 2.5 megohm, variable-resistance, 40-turn potentiometer†
R_{10}: 220,000 ohms, ½ w

Capacitors

C_1 and C_2: 250-μf, 150-v electrolytic condensers
C_3 and C_4: 50-μf, 50-v electrolytic condensers
C_5, C_6, and C_7: 2-μf metalized-paper condensers

Chassis

8 × 10 in., aluminum

Sockets

Three standard octal sockets

Tubes

Tube 1: OC3, 105-v voltage regulator
Tube 2: 6SN7GTA

Relays

Relay 1: single-pole plate circuit relay, 10,000-ohm coil (KCP5)‡
Relay 2: single-pole relay, 115-v, 60-cycle, 2,200-ohm coil (KRP11A)§
Meter relay: double-contact, zero center, 10–0–10-μa, d-c relay‖

pH Amplifier

Electronic pH meter# **

Motor

2-rpm, 115-v, 60-cycle reversible sychronous motor††

Electrodes

Flow-through calomel and glass electrodes

Battery

Size D, 1.5 v

Switch

Double-pole toggle

Pilot light

6.3-v lamp

Recorder (optional)

¼-in., 40-revolution, spiral-geared shaft with follower set screw and pen arm

* Stancor PS 8415; a product of Chicago Standard Transformer Corp., Chicago, Ill.
† Series E; a product of Beckman Instruments, Helipot Corp., Newport Beach, Calif.
‡ Manufactured by Potter & Brumfield, Princeton, Ind.
§ Versatrol; a product of Assembly Products, Chesterland, Ohio.
‖ Model W; a product of Beckman Instruments, Fullerton, Calif.
Model 115; a product of Photovlt Corp., New York, N. Y.
** Manufactured by Beckman Instruments, Fullerton, Calif.
†† Series 430; a product of Bristol Co., Waterbury, Conn.

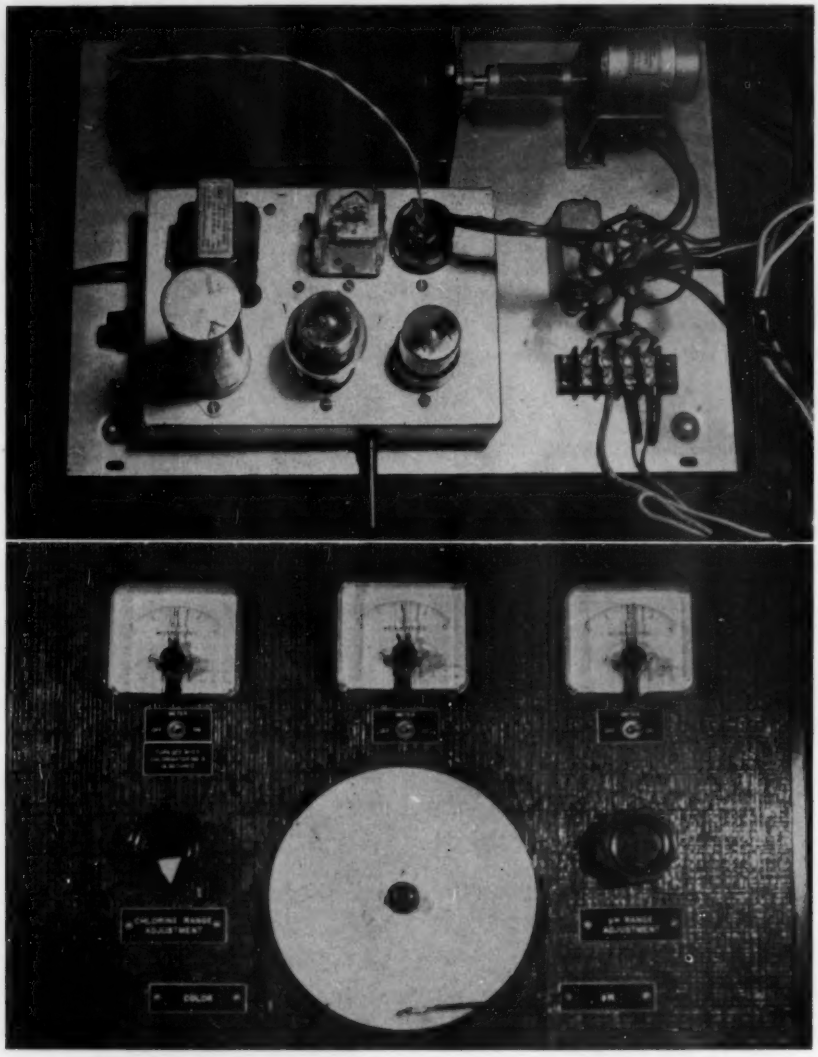

Fig. 3. Internal View and Control Panel of Automatic pH Control

The meter at the upper right of the control panel (lower photograph) is a double-contact relay that controls the position of the motor-driven potentiometer (upper photograph). On the control panel, a disc recorder translates the movement of the potentiometer into a continuous record of pH variations.

work, maximum plate current flows through Relay 1, which closes and disconnects the caustic-soda pump from the circuit. The instantaneous closure of the contacts on Relay 2 throws a negative voltage across the R-C network (R_9, R_{10}, C_5, C_6, and C_7), charging the network to a maximum and causing the plate current of Tube 2 to fall to zero, as the tube is at cutoff voltage. Relay 1 is deenergized in this condition and the caustic-soda pump begins operation. The length of time that Tube 2 remains at cutoff is dependent upon the rate of current discharge through the fixed resistance R_{10} and the variable resistance R_9. The equation for the circuit time constant with these components is

$$t = 2.86\ rC \ldots\ldots\ldots (1)$$

in which t is the time, in seconds, C is the capacitance, in microfarads (μf), and r is the resistance, in megohms. With the fixed capacitance of 8 μf ($C_5 + C_6 + C_7$) and the fixed resistance, R_{10}, of 0.22 megohm, Eq 1 becomes

$$t = 22.88\ r \ldots\ldots\ldots (2)$$

where

$$r = R_9 + 0.22.$$

The variable-resistance potentiometer R_9, which provides 2.5 megohms of resistance in 40 turns, is the most important item in the circuit (Fig. 3), as, with its unusual resolution time, constants of a fraction of a second can be obtained within a few degrees of shaft rotation. The double-contact meter relay controls the resistance value of the potentiometer R_9 by means of the reversible motor connected directly to its shaft. These contacts, which are a part of the meter relay, are located at equal distances from electrical zero, with the needle contact mechanism floating in the dead zone between the two contacts. If there is no disparity between the bridge output and the incoming signal from the pH amplifier, the needle contact remains in a position of balance and the motor-driven potentiometer R_9 is inoperative. If an error signal does appear across the meter relay, the imbalance closes the needle mechanism with the appropriate contact and, depending on the pH variation of the effluent, either increases or decreases the value of R_9 according to the direction of motor rotation. If it is desired to incorporate a recording mechanism into the controller a 40-turn spiraled shaft may be inserted between the motor and the potentiometer together with a pen arm mechanism and some form of strip or circular chart. This is illustrated in Fig. 3.

The self-contained power supply is half-wave rectified and heavily filtered to reduce ripple. Regulation is necessary in order to obtain a uniform operating point for Relay 1. The bias voltage supply is a voltage doubler which receives its a-c input from the 6.3-v filament taps on the power transformer. The bias voltage adjustment is variable from zero to 13 v by means of the bias voltage control R_8. The a-c supply on the filament is left floating, as the positive side of the d-c output is grounded. With a fixed bias voltage of -9 v d-c applied to the R-C network and to the grids of Tube 2, the time constant for the system (length of pump operation per 10,000-gal cycle) varies from 3.7 to 27.5 sec as R_9 is varied from zero to 40 turns. Other time constants can be obtained by either increasing or decreasing the bias voltage or the capacitance in the R-C network.

Application

Two physical problems of the automatic pH control device are uniform dispensing of the caustic-soda solution to the plant effluent during a 10,000-gal cycle and the distance the electrode assembly should be placed downstream from the point of chemical injection.

If Q is the daily flow of water (in millions of gallons) and t is the time (in seconds) to pass 10,000 gal, it can be shown that

$$t = \frac{864}{Q} \quad \ldots\ldots\ldots (3)$$

Eq 3 is a converging series, as the larger values of Q produce smaller increments of t. Thus a pump operating at a fixed calibration point might have a considerably longer idle period at a minimum flow than at a maximum flow, which would result in the entering of caustic soda into solution in slugs. This condition is very undesirable and is one of the most troublesome features of the time-impulse method of chemical treatment. In systems that flow by gravity, a possible solution is to inject the caustic soda into at least a 4-in. standpipe or surge chamber (open to atmosphere) in which water is being added at a constant rate ($\pm$ 35 gpm). The caustic soda and makeup water in the chamber provide a slight additional head above the normal hydraulic gradient and result in a uniform gradual dispensing of the soda to the effluent.

The distance, S, downstream from the point of chemical injection to the point at which a good mix might be expected for pH detection is directly related to the size of the plant effluent conduit and the maximum predictable flow. As a general rule, for a good mix S should be at least 50 ft for a 4×4-ft rectangular conduit and a maximum flow of 26 mgd.

Summary

The automatic pH controller operates on the basis of proportional and floating controls and has the following features:

1. An accuracy of pH control within ±0.05 pH units from the desired value
2. Fast recovery
3. Low cost
4. Simplicity of construction
5. Ease of operation (one manual adjustment)
6. Dependable operation and long component life
7. Recording of pH variations on a strip or circular chart for a permanent record.

Turbine Pumps for Booster Service

Clinton C. Warren

A paper presented on Apr. 24, 1959, at the Pacific Northwest Section Meeting, Vancouver, B.C., by Clinton C. Warren, Pres., Cornell Mfg. Co. and Pump, Pipe & Power Co., Portland, Ore.

THE pump ranks second only to the electric motor as the most widely used industrial machine. Modern pumps can be designed to handle anything that flows, and they are now used to pump highly volatile ether, thick abrasive sludges, and molten metals at high temperatures. There are hundreds of industrial pumps of all kinds, ranging in differences from small details to entire principles of operation.

Centrifugal Pumps

Centrifugal pumps, by far the most widely used, are ideally suited for water utilities. They are classified according to:

1. Energy conversion: volute or diffuser
2. Impeller: radial; Francis; mixed flow; propeller; single or double suction; open, semiopen, or closed; or single or double curvature vanes
3. Number of stages
4. Axis of rotation
5. Type of casing
6. Method of drive.

The centrifugal booster pumps used by water utilities can be either regular centrifugal (volute) or turbine centrifugal (diffuser). In a volute pump, the impeller discharges into a progressively expanding spiral casing, proportioned to reduce the liquid velocity gradually. Some of the velocity energy of the liquid is thus converted into static pressure. In a turbine pump, generally called a vertical diffuser pump, vaned diffusers convert velocity head to pressure head. In recent years, because of its advantages over the volute type, the vertical turbine pump has become more widely used by water utilities.

There are three basic types of vertical pumps, depending upon the impeller used: radial flow, mixed flow, and propeller. These basic types may overlap. Because the operating characteristics of pumps are determined by the design of the pumping element, which consists of the impeller and the companion bowl or diffuser, modifications of the three basic pumping elements result in a wide range of pump characteristics.

Selection of Pumps

One of the problems facing engineers is how to select and apply the pump that will best meet a given set of conditions. To many engineers, pump application is a hazy subject with much miscellaneous information available that is difficult to relate to the problem at hand. There is no substitute for experience in interpreting raw

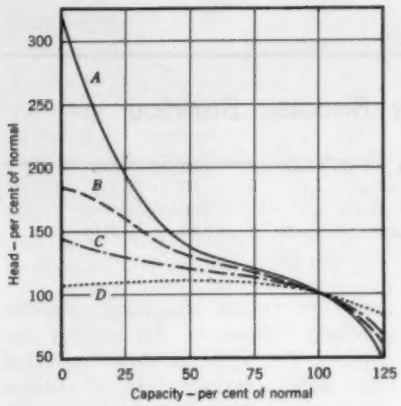

Fig. 1. Head-Capacity Curves for Pumps of Different Specific Speeds

A, B, C, *and* D *are curves of axial-flow, mixed-flow, turbine, and centrifugal pumps, respectively. The specific speeds of these pumps are:* A, *10,000;* B, *5,000;* C, *3,000; and* D, *500.*

data from field analyses and designing a complete pump installation.

In the design of a pumping system, a number of factors must be considered: head, capacity, piping, drives, nature of fluid to be pumped, and economy. Often, during system planning, important factors of economy that originate with the project and continue through its useful life are overlooked. Pump location, for example, may produce worthwhile power savings if it is determined from a study of head conditions, pipe sizes, and proper fittings, with expanding future loads in mind. The hydraulic consideration receives more attention generally than the economic factors, although the latter are an inseparable part of every pumping system problem. The user seeks the lowest cost per gallon pumped, which should be determined from the original cost, operating costs, estimated life,

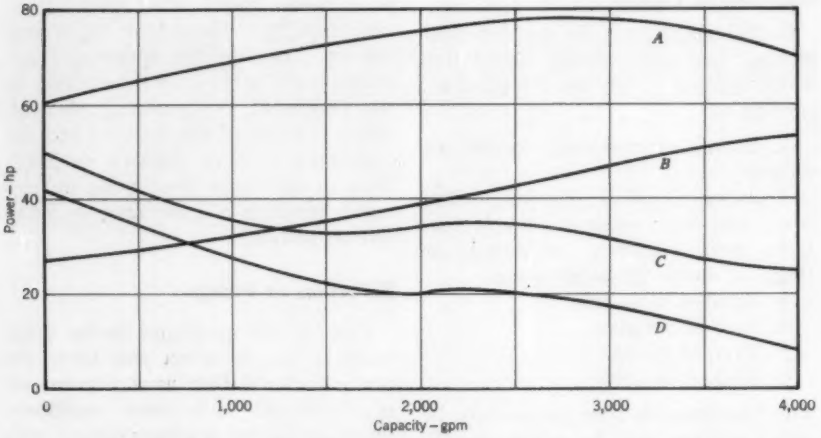

Fig. 2. Typical Performance of Pumps With Different Specific Speeds: Horsepower

A, B, C, *and* D *are curves of turbine, centrifugal, mixed-flow, and axial-flow pumps, respectively. The specific speeds of these pumps are:* A, *3,500;* B, *4,300;* C, *7,000; and* D, *12,300.*

cost of maintenance, cost of money, and salvage value.

Turbine Pump Efficiency

All turbine pumps originally developed for deep wells are of the diffusion-casing, vertical type, used for over 30 years. The turbine pump has been perfected to a high degree and, at present, is the most efficient multistage centrifugal pump. Laboratory pump efficiencies up to 90 per cent for 1,200-gpm pumps operated at 1,760 rpm are on record. Several factors have contributed to the high efficiency of this pump:

1. Favorable specific speeds of 2,500–4,000, not used in any other multistage pumps: with increasing specific speed, the impeller profile gradually changes from a straight radial to a conical mixed flow, and finally to a straight axial flow
2. Improved hydraulic design of the casing, with liberal stage spacing
3. Keen competition among many companies, simple and inexpensive designs, large sales volume, which permit continuous improvements and changes in design
4. Owing to stage arrangement, the absence of interstage leakage and leakage from balancing devices (as hydraulic thrust is taken up by the motor thrust bearing) and the use of high-pressure stuffing boxes or the absence of high-pressure boxes in inverted construction, when suction pressure exists at the packing gland
5. Better hydraulic features of vertical arrangement: diffuser vanes are arranged more in an axial direction and developed in one piece without sharp turns, allowing ample space between impeller and vane; the possibility of using impellers of different diameters and widths
6. Prevention of overloading
7. Location of motor above flood, better ventilation, cleaner operation
8. Controlled submergence of the pump assembly for more efficient operation.

Specific Speed

A variation of hydraulic characteristics of a centrifugal pump ties in with its range of specific speed. Specific speed is a term used to classify impellers according to their performance and proportions, regardless of their rotative speed or actual size. It is a function of the proportions and is used only as a characteristic number. It is mathematically expressed as

$$N_s = N\sqrt{\frac{Q}{H^3}}$$

in which N_s is the specific speed; N, speed of rotation (rpm); Q, capacity (gpm); and H, head (ft).

The lower the specific speed, the higher is the head per stage that can be developed. Generally accepted values for low specific speeds range from 500 to 1,000; medium specific speeds, from 1,500 to 4,000; and high, from 5,000 to 20,000. As the specific speed increases, the impeller goes from radial flow to mixed flow and, ultimately, to axial flow. Also the capacity increases and the head per stage decreases.

High-Specific Speed Pumps

Pumps with high specific speeds produce the greatest capacity from a fixed-diameter pump assembly, but at a low head per stage. These pumps handle gas and air better and last longer when pumping sand than those with high

head per stage. They are more expensive to manufacture, because of the need for complicated core work and molding and because of the greater number of stages needed for a given head requirement. These pumps are, however, more versatile for variable-head applications.

As the specific speed increases, the head-capacity curve becomes steeper (Fig. 1)—that is, the ratio of shutoff head to the head developed at the point of best efficiency increases. Also, the head-capacity curve will tend to be flat near the best efficiency point toward the shutoff head. In some instances, this flatness develops into a reversal. Caution should be exercised when using the pump at or near this critical range, because the point of best efficiency may be very close to this flat area.

The prevention of overloading is a very desirable feature of centrifugal

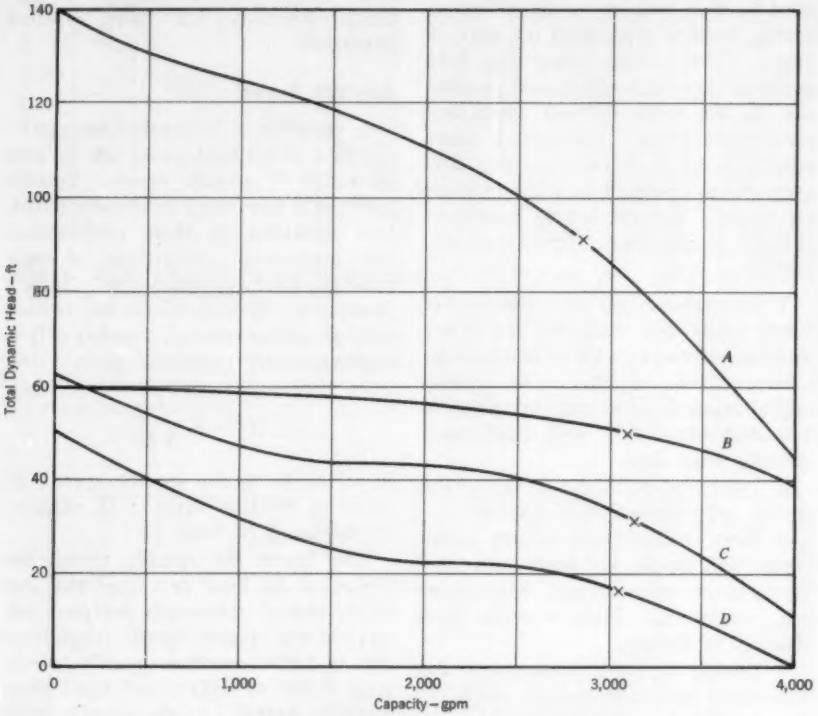

Fig. 3. Typical Performance of Pumps With Different Specific Speeds: Head Capacity and Efficiency

A, B, C, *and* D *are curves of turbine, centrifugal, mixed-flow, and axial-flow pumps, respectively. The specific speeds of these pumps are:* A, *3,500;* B, *4,300;* C, *7,000; and* D, *12,300. The cross mark on each curve is at the point of best efficiency. These are the same pumps as in Fig. 2.*

pumps, eliminating overloads in the range of specific speeds from 2,500 to 4,500, at which the maximum horsepower is required at or near the best efficiency point.

Low-Specific Speed Pumps

Turbine pumps that deliver high head per stage have lower specific speeds than those that deliver low head per stage. Comparison of these two types of pumps—capacities being equal—reveals that the former has a pump assembly with a larger diameter, but with fewer stages for a given head requirement. Therefore, the well diameter often determines which of the two pumps can be used. The diameter of the bowl assembly imposes no limitations on the use of turbine pumps for booster service.

Pumps with high head per stage have a flatter head-capacity curve and a horsepower curve that rises with an increase in capacity. They produce more suction, develop less downthrust, and cost less to manufacture than pumps with low head per stage. In comparing the two pumps, it should be realized that their characteristics overlap in certain areas. Therefore, which to use depends on the particular application and the customer's needs.

Head-Capacity Curves

Because of the varying characteristics of centrifugal pumps, it is desirable to see the graphic relationship between the head and capacity, horsepower, and efficiency of a pump under consideration (Fig. 2 and 3). These curves show the behavior of the pump under different pressures and capacities. A common misconception about centrifugal pumps is that they supply the prescribed head at all times. Actually, the pump handles only what it meets in the system; its performance is quite elastic. The head-capacity relationships are curved rather than straight lines, and the curve of a pump definitely fixes its operating range. Also, the pump can be operated only at some point along the curve. A rising head-capacity curve is desirable for wide fluctuations in pumping heads, where friction head is a dominant factor, as in a booster pump used in parallel. A flat head-capacity curve is desirable

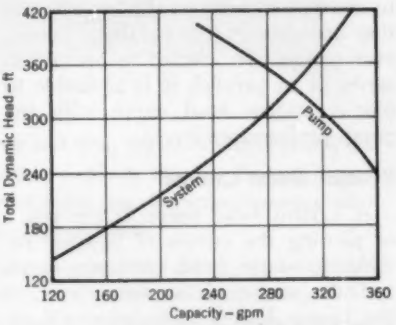

Fig. 4. System and Pump Head-Capacity Curves

By plotting these two head-capacity curves together, pump performance can be analyzed to see if it is fit for a particular system.

where even pressures are wanted over a wide operating range, as with pumps boosting into dead-end lines. A falling head-capacity curve, in which the shut-off head is close to the operating head, is undesirable where pumps are used in parallel or where the total head is caused largely by elevation. In parallel operation, in order for each pump to contribute individually or collectively into a common discharge manifold, sufficient additional head is needed beyond the operating range to open the check valve and get on the

line. Often, this requires 117 per cent of shutoff head over normal operating head. When a pump is placed on the line, it goes to shutoff head and then back to operating head.

A centrifugal pump, of either the turbine diffuser or volute type, is ideal as a booster utilizing the positive pressures from gravity or from another pump and adding its own head-capacity characteristics. When two pumps are used together to boost pressure, they are connected in series; when used to increase capacity at the same heads, they are connected in parallel. Whenever pumps are selected to operate in series or in parallel, it is advisable to plot a system head curve with the pump performance curve.

System Head Curves

A system head curve is the result of plotting the curves of pipeline resistance, static head, pressure head, and the variations in water level, if the source lowers with increased capacity. The operating conditions of the pump are best determined graphically by plotting on the same sheet to the same scale both the pump and system head-capacity curves. The operating point is obtained by the intersection of the two (Fig. 4). The procedure is simple when only one pump and one pipe of constant diameter are involved, but becomes more complex with several pipe sizes and pipe grids. By plotting a system head curve against a pump head curve, the performance of a pump can easily be analyzed to see if it can do the job within a system.

Summary

Choosing the proper booster pump can only be done after all the requirements and limitations of capacity, head, and supply characteristics are known and carefully correlated with the total requirements. Good engineering dictates a careful study of conditions to insure the use of efficient equipment and the most economical size and arrangement of piping. It is probably true that a pump is no better than its piping system and installation.

The vertical turbine booster pump can be designed to meet different requirements. It has excellent head-capacity characteristics and works well in series and parallel installations at low maintenance costs.

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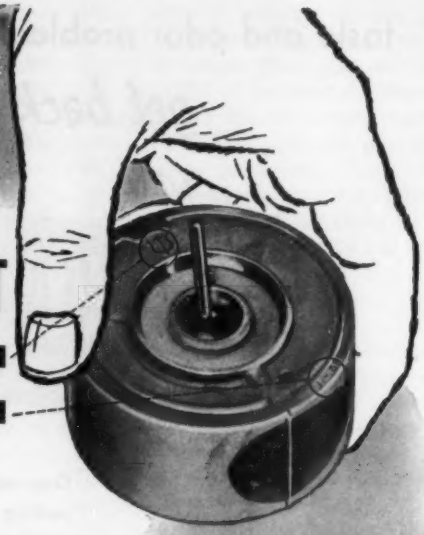

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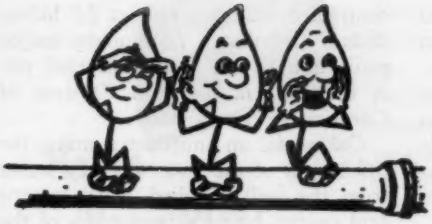


Percolation and Runoff

More of San Francisco than could be included in last August's pages (P&R p. 35) merits mention. There were, for instance, the colorful floral welcome that greeted AWWAers in Golden Gate Park (see cut) and the movie men who were grinding away all week at the Civic Auditorium to record the conference story for screening at section meetings in the coming year. There were the golf tournaments —the men's at California's oldest golf course, the Presidio, and the ladies' at the California Golf & Country Club— and there were, from everywhere but the golf courses, *statistics*. We did learn that there were 108 players, among whom Dave Fiscus, San Marino Div. manager for the California Water & Telephone Co., was the winner of the water workers' trophy and Russ Olsen (Badger Meter Mfg. Co.) of the manufacturers' prize, but the scores were as unrevealed as the ladies' ages or even scores or even winners. Other facts and figures, though, abounded:

A total of 3,211 registered, a fact which made AWWA Secretary Ray Faust $94 richer, his guess of 3,212 taking the Board of Directors registration pool.

Of the 3,211 total, 785 were ladies, 1,376 were in water utility work or related fields, and 1,050 were manufacturers' representatives. Last year the breakdown was 687 ladies, 1,314 water utility men, and 1,023 manufacturers; in 1957 the totals were 669 ladies, 1,378 water utility men, and 1,021 manufacturers.

Of the 3,211, 30 per cent preregistered, 30 per cent registered on Sunday, and 28 per cent registered on Monday. Next year, it is hoped, at least 50 per cent will take advantage of the convenience of preregistration, made available for the first time this year.

The 3,211 registrants drank 5,013 cups of free Pepsi Cola, second only to the record of 6,888 consumed in

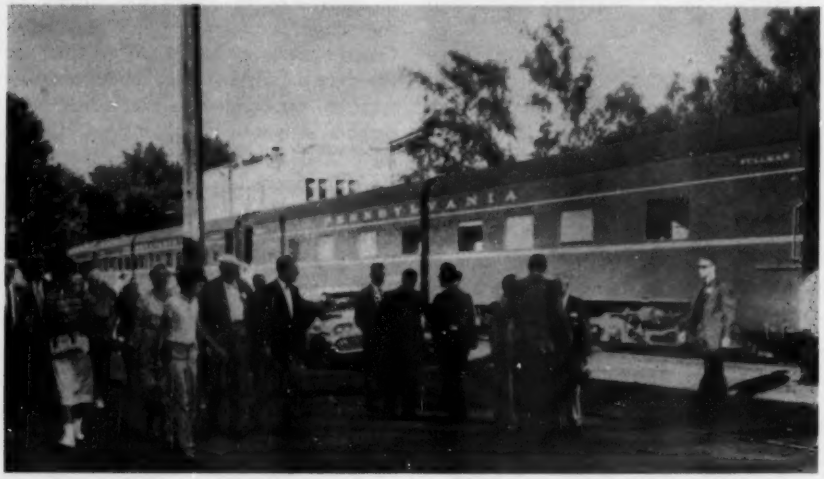
(Continued on page 50 P&R)

(Continued from page 49 P&R)

Atlantic City in 1957. Next May Bal Harbour, Fla., should top the pop record.

Of the 3,211 registrants, more than 100 came the scenic route, via AWWA's Northwest Tour, and made history en route as theirs was the first train in some twenty years to pull into Corvallis, Ore. (see cut).

More of San Francisco, we hope, but not for the moment, that's Bal Harbour dead ahead—May 15–20, 1960.



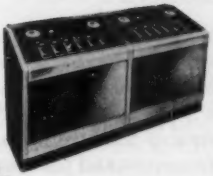
'Do It Now!' went and done it, it seems. At any rate, the midyear review of construction in the F. W. Dodge Corp. *Building Business* notes that, although utility construction contracts were down 20 per cent from last year's total, and although all other utilities declined, "contracts for water supply systems rose 21 per cent." But before we sprain any arms at backpatting, we ought to remember that the backlog of water supply projects has been increasing faster than the work contracted, standing now at 2.7 billion dollars and that a good many major projects have not been contracted yet. A brief list in the Jun. 29 issue of *Chemical Week* included:

California: an aqueduct running the full length of the state to carry water from the well supplied North to the arid central and southern parts of the state; estimated cost, $12.5 billion; additional water supply, 19.6 bgd

New Jersey: reservoirs for surface water and facilities for pumping additional water from the Delaware River, also development of ground water supplies; estimated cost, $170,000,000 first stage; $575,000,000 second stage; target dates, 1970 first stage, 2000 second stage; additional water supply, 420 mgd first stage, 1.158 bgd second stage

Ohio: diversion of water from Lake Erie by means of a canal to be linked with the Cuyahoga River, another canal at the other end of the river to carry the water back into the lake; estimated cost, $56,000,000 first stage, $200,000,-

(Continued on page 52 P&R)



Here's Water Plant Control You Can Depend Upon!

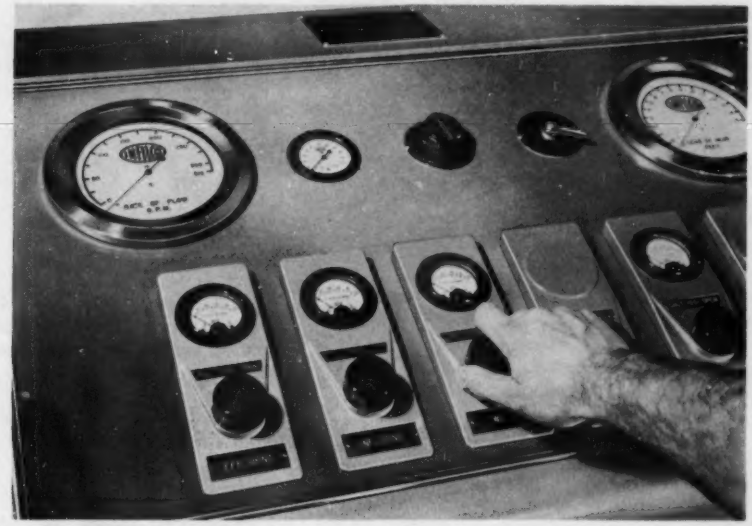
This complete pneumatic system includes all the essential elements for the operation of water treatment plants. It is used for raw water flow control, flow measurement, chemical proportioning, level control and control of gravity filter operation.

Reliable mechanisms produce controlled air pressure for actuating meters, feeders and controllers and for measuring flow, head loss or water level.

The simplicity of this design offers you important plus values. Measurements are accurate and instantaneous. Operation is dependable. Maintenance is simple. *Write for Bulletin 1100.*

C.-A.-P. SYSTEM®

INSTRUMENTS



INFILCO

INFILCO Incorporated, General Offices—Tucson, Arizona
Field offices throughout the United States and other countries.

911

(*Continued from page 50 P&R*)

000 second stage; target dates, 1980 first stage, 2000 second stage; additional water supply, 2.7 bgd first stage, 4.3 bgd second stage

Oklahoma: a 200-mile canal to tie in with Arkansas River Basin project; estimated cost, $200,000,000; target date, 1972; additional water supply, 1 bgd

Rhode Island: large water district being created in Providence area to cover city and neighboring towns, piping surface water to different areas where treatment plants will be built; estimated cost, $14,400,000; target date, 1975; additional water supply, 61 mgd

Texas: a large canal across entire state to intercept flow of seven rivers and redistribute the water to arid regions; estimated cost, $1.1 billion; target date, 2000; additional water supply, 7.1 bgd.

Just these few projects add up to an estimated cost of $15 billion for a total of 36 bgd. And they, of course, are only a beginning. *Do It Now!*

Bernard L. Werner has been appointed director of public works at Baltimore. In his new position he will have charge of the ten bureaus composing the Dept. of Public Works, including the Bureau of Water Supply, which he headed as water engineer for 5 years.

Et tu, Esch. coli? was all that we could say to the news from a recent meeting of the Assn. of American Physicians that a corollary of the success of sulfanilamide, penicillin, streptomycin, and the other wonder drugs has been the stirring up of those normally harmless inhabitants of our bowels and other organs—*Pseudomonas aeruginosa, Proteus mirabilis, Aerobacter aerogenes,* and *Escherichia coli.* Informed speculation is that these organisms were formerly held in check by substances secreted by such killers as streptococcus and pneumococcus, which now, having been eliminated, are no longer available to protect against the misanthropic tendencies of these decay bacteria. Less informed, but perhaps more interesting to water works men, is the speculation that water treatment plants have done their work so well over the years in cleaning up coliform pollution that their customers have lost their resistance to the organisms. Whatever the cause, though, we can but mourn:

Et tu, Esch. coli? Then fall, humanity? For if good friend to all, who lies in every bowel, now turneth killer and would do us in, then may we better soon succumb than later to some lesser friend, less likely to stick with us to the rotten end! But wait, hold off, do nothing for the nonce. Have we not heard from Gaul of older, wiser ways *à notre santé?* Yea, that we have, through *Newsweek,* thus and so:

> As if to confirm the hidden wisdom in the traditional Gallic toast "to your health," France's High Committee of Studies on Alcoholism has just reported that a good red Bordeaux can kill the bacilli of typhoid fever as well as staphylococci and other germs on contact. As a germicide the experimenters rated wine almost on a par with penicillin.

And wine, of course, has long been known to soothe, rather than stir up our coliformic convivantes.

K. A. Steel Chemicals Inc. has moved its offices to 5555 N. Sheridan Rd., Chicago 40, Ill.

(*Continued on page 54 P&R*)

Allis-Chalmers introduces...

New vertical turbine pump—the prime pump that needs no priming

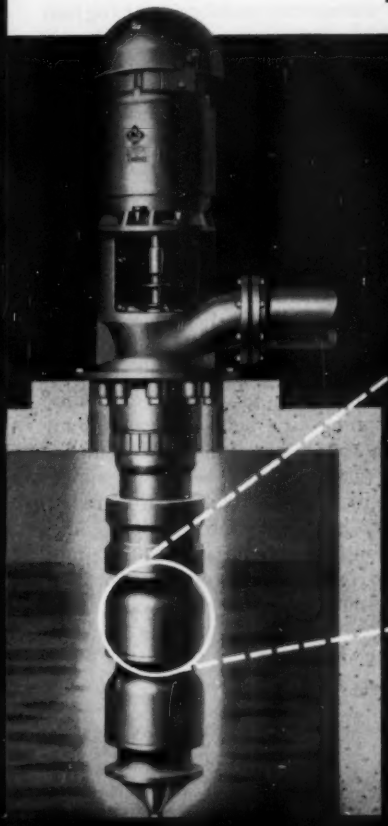
Now Allis-Chalmers brings its 85 years of pump experience to the short-coupled vertical turbine-type field. This addition not only rounds out industry's most complete single source for pump installations, it offers many advantages wherever liquids are to be pumped. Standard sizes for heads up to 400 ft or more, and capacities ranging from 20 to 8000 gpm.

Pressures can be increased by simply adding a stage to the existing pump without increasing space requirements. Equipment and installation costs are low. Motor and discharge nozzle are supported by a single, small foundation. There's no need for suction pipe, interlock controls or priming equipment. Allis-Chalmers hollow-shaft motors remove the danger of open couplings.

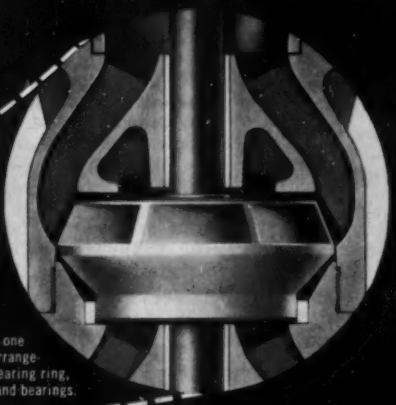
Allis-Chalmers pump experts will be happy to tell you about this new addition to an outstanding line. Contact your A-C representative or distributor, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

A-1163-JAW



Many advantages — Self-priming • eliminate suction piping costs • save space, motor support and discharge nozzle are integral • low first cost • increase pressure easily • operate quietly • low maintenance with one stuffing box • no motor flooding.



Cross-section of one stage showing arrangement of bowl, wearing ring, impeller, shaft and bearings.

Many applications — Water systems, irrigation, condenser systems, bilge and sump service, dry docks, fire equipment, filter washing, recirculation, transfer pumping, process pumping, cooling condensers and diesel jackets, air conditioning, caisson and mine dewatering, general-purpose pumping.

(Continued from page 52 P&R)

The sticks and stones philosophy that we learned as a child is now being systematically undone by the Engineers Joint Council. Names can, too, hurt you, says EJC, in a series of ads appearing in *Editor & Publisher*—not just bad names, either, but wrong ones. And most people, it seems, call engineers "scientists" or "technologists," which are not bad, but which is bad! With the idea that people should say "engineer" when they mean "engineer" (see ad above), we are in complete sympathy; engineers ought to reap full credit and take full blame for the things they do. But with EJC's corollary complaint—that people do not properly respect the title "engineer"—we cannot go along. From the time we were *so* high and felt that we would be eternally happy if we could only be an "engineer"—albeit a "locomotive engineer"—we have always thought that the title "engineer" was really something. And we, it appears, are not the only one so impressed. Salesmen would certainly not be calling themselves "sales engineers," or public relations men "opinion engineers," if the title bore the slightest hint of disrepect. And when the title is so generally appreciated that our janitor likes to be known as a "maintenance engineer," how can any one doubt that "engineer" has it made? As a matter of fact, we were toying with the idea of joining the profession ourself, as a grammatical engineer, until we read EJC's theme: "Scientists make it known, but engineers make it work!" That, of course, puts us in our scientific place. Ah well, names will never hurt US!

One of a series

Say Engineer, When You Mean Engineer

Somehow it's become popular to speak of science and technology—popular, that is, with everyone but engineers.

Engineers are in a partnership with scientists in this great industrial nation of ours—designing its products, constructing its communications, and even producing its missiles.

The U. S. is reaping fruits of a highly developed technology—a vast body of engineering and scientific know-how. And the fellows with that know-how are scientists and engineers.

So when you speak of these fellows—or write of them—call them what they call themselves. Call them engineers.

Engineers Joint Council
29 West 39th St., N. Y. 18, N. Y.
For information, call Pennsylvania 6-9220

A statewide monitoring program has been set up by the Pennsylvania Health Dept. to determine how much, if any, radioactivity exists in public water supplies. Samples of both raw and treated water are being collected daily by sixteen water utilities cooperating in the program, and composite samples are to be forwarded once a month to Harrisburg for analysis. The program has the twofold purpose of determining what radioactivity is present in water supplied to the public and the efficiency of treatment methods for eliminating the hazard. In addition, results of the program will be of value in planning civil defense measures for public water supplies. It is emphasized that there has been "no appreciable increase in the amount of radioactivity in public water supplies, due to fallout, in recent years," but the new testing program will establish present levels of radioactivity in water supplies, so that any changes can be quickly detected.

(Continued on page 56 P&R)

GRAVER
WATER
CONDITIONING
CO.
Division of
Union Tank Car Company

216 WEST 14TH STREET, NEW YORK

V.J.C.-
This may be of
interest to you
H.T.S.

Inter-Organization Correspondence

TO: General Manager
FROM: Technical Director
SUBJECT: Review of Reactivator History

Approaching the 20th anniversary of the Reactivator we would like to summarize briefly its rise to the leading position among solids-contact water clarifiers and softeners. From the beginning, two basic elements were incorporated in the Reactivator design: positive sludge recirculation and mechanical sludge removal over the entire bottom area. Twenty years have confirmed the soundness of these original concepts.

By a constant effort to improve design performance, some important modifications have been made. (1) The method of inducing solids-contact was changed from air to impeller-pump to produce gentle and effective sludge recirculation. (2) The geometry of the machine was modified to get the best conditions for separation of solids from water. (3) Increased knowledge of sludge characteristics led to the redesigning of the sludge removal system.

As a result of these changes the Reactivator is able to provide: (1) solids-contact with the highest concentration of solids for the longest period of time; (2) an increase in throughput rate up to 2½-3 gpm/sq. ft. in certain cases; (3) more reliable and efficient mechanical sludge removal; (4) outstanding surge-proof characteristics.

Probably the most significant work in our program to improve the machine has been our very extensive field studies. We have had the opportunity to work with units from 8 to 125 ft. round and square on applications as widely divergent as...clarifying Arctic tundra lake water...softening and clarifying Mississippi and Colorado River waters...reducing color in Louisiana bayou water...treating hard, clear midwestern deep well supplies, and many more. The complete story of these applications is contained in our new Reactivator Bulletin WC-103C.

The sum total of our experience and knowledge has gone to make the present-day Reactivator the most versatile and reliable solids-contact unit on the market. It is gratifying to all of us to have participated in the development of such a machine.

M.L.

ML/lz

Technical Director

(Continued from page 54 P&R)

The wheel seems to be rolling fast toward oblivion. Its first spin in that direction came last spring when Albert Sfredda of Bethlehem, Pa., won a first prize in the 1959 Mars (pencil, not planet) Outstanding Design Contest with a truck that ran on squares instead of wheels (see cut). Sfredda's idea is that the square shape gives superior traction in mud, sand, snow, or on uneven terrain by bridging ruts instead of sinking into them. The squares, it is claimed, run smoothly in any relative position without synchronization. They are designed for use on heavy trucks, jeeps, and farm or construction machinery, on which "they will permit speeds of up to 35 mph." Then, in July, Curtiss-Wright Corp. announced that it would begin production in November of a 300-hp "air-car" that would travel neither on wheels nor squares, but on a cushion of low-pressure, low-velocity air, at a height of 6–12 in., over land, water, swamps, or mud, requiring no expensive paved surfaces and no bridges. The air-car, which is said to attain speeds of 60 mph, is now available for demonstrations at Caldwell, N.J., where pictures of the air-trucks and air-buses, of which prototypes are now in process, are on view. And at Virginia City, Nev., where Curtiss-Wright has a plant, a test area with 25 mi of the special low-cost road (cleared of large obstructions and stabilized with a coal-based road paving binder for dust control and washout prevention) is being set up to demonstrate performance in mountainous and desert terrain.

The implications of both squaremobiles and airmobiles are almost unending, but it is the airmobile that is bound to have the greater, because it has the lesser impact. Thus, on airmobile highways, water lines can be laid without concern about traffic load or paving. And in our society, it will, no doubt, be the blowhard, rather than the square, who takes over from the big wheel.

(Continued on page 58 P&R)

You buy
greater
DEPENDABILITY
with
WATCH DOG
WATER METERS
GAMON METER DIVISION
NEWARK
NEW JERSEY
WORTHINGTON

(Continued from page 56 P&R)

Retired after 20 centuries of service, still in working order, was the record of a plug valve that had been in daily use at the reservoir of a Roman villa at Frascati since before the birth of Christ. After it was replaced in 1956 by the peasants who had used it in drawing water for irrigating their fields, Dr. Mario Fera, engineer and metallurgist for an Italian petroleum engineering firm, examined it and traced its history as part of a study of valves of that period. Reporting at the Fifth World Petroleum Congress in New York, Dr. Fera pointed out that the valve measured up to present ASA standards. He also described a giant valve salvaged from a yacht owned by Emperor Caligula (37 AD), noting that:

The valve is made of a zinc-free, lead-rich, anticorrosion, antifriction tin bronze of a composition very similar to ASTM B1443D cast acid metal used for valves, parts, and fittings, for acid service, and to ASTM B1443E antifriction bronze used for bearings and the like.

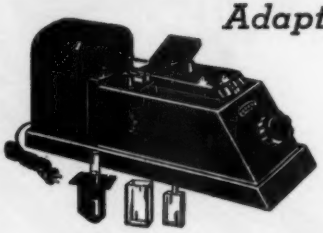
All of which merely confirms the fact that Rome didn't fall, it had to be disassembled.

Water flowed like money in Reno last August as a well yielding 3,500 gpm was brought in by Layne Texas Co. And to make this Nevada miracle even more miraculous, the 5 mgd produced is sand free in an area where well waters are known for their high sand content. Behind the miracle were a careful study of the geology, hydrol-

(Continued on page 60 P&R)

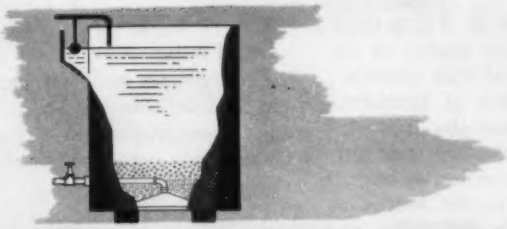
KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

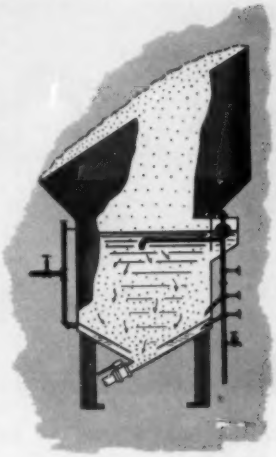
KLETT MANUFACTURING CO.
179 EAST 87th STREET · NEW YORK, N. Y.



BRINE FILTRATION

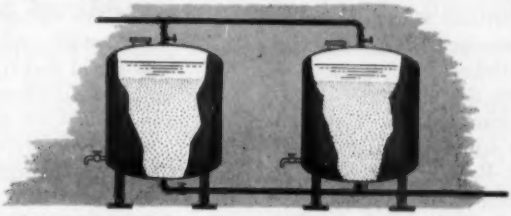
How it can affect design of water softening installations

Whichever filter medium you select—sand, gravel or anthracite, undissolved crystals of rock salt—this much is clear: dissolver design and regeneration expenses are bound to be affected. For example: Provision should be made for periodically removing the accumulated insolubles from the filter bed. Design of filters should incorporate the necessary cleanout facilities. And a brine-filtration setup that performs well with one type of salt may be inadequate with another.



The growing amounts of brine in use in today's large-capacity water softening installations complicate filtration problems. That's why treatment plant designers and builders are turning more frequently to International Salt Company. With over 50 years of experience and continuing research in all phases of salt handling and brine production, International can suggest many new and practical ideas in connection with salt purchase, storage and dissolving for regenerating ion exchangers. There is no charge for this service.

Service and research are the extras in STERLING SALT



INTERNATIONAL SALT CO., INC., SCRANTON 2, PA. • **Sales Offices:** Boston, Mass. • Buffalo, N. Y. Charlotte, N. C. • Chicago, Ill. • Cincinnati, O. • Cleveland, O. • Detroit, Mich. • Newark, N. J. New Orleans, La. • New York, N. Y. • Philadelphia, Pa. • Pittsburgh, Pa. • St. Louis, Mo.

(*Continued from page 58 P&R*)

ogy, and ground water quality of the area, the use of gravel wall construction, and the inclusion of precision-manufactured screens of the "bar-lug" type. Impressed with this and with the fact that the flow was the largest of its kind known "in the four-state area and, perhaps, in the entire nation," we were almost equally impressed with Layne's flowmeter until we were told that the photo below was "merely for publicity." Be that as it may, C. P. Bryant, construction superintendent for Layne on the project,

seems impressed. Oh yes, holding the flowmeter we mentioned above is Phillys Paul.

George A. Marshall, superintendent of the Portland (Ore.) Bureau of Water Works since 1947, will retire on his 70th birthday in January. He has been with the city since 1913. Succeeding him will be Ted Suderberg, currently supervisor of Portland's Div. of Sewer Repair, who will act as special assistant to Marshall until the changeover in January.

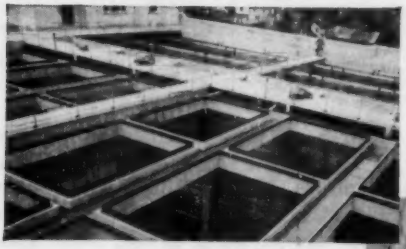
Legal notes: *Fire service adequacy.* A Pennsylvania wood products manufacturer complained to the state public utility commission that a local water company was not providing fire service at pressures meeting NBFU standards. The commission's dismissal of the complaint has been upheld by the state superior court on the grounds that the commission is not bound to accept the standards of the NBFU or any similar group and should judge each case on its merits. Noting that improvement of pressure would require a considerable outlay by the utility primarily for the benefit of a single customer, the court said: "A utility rendering reasonably adequate service should not be subjected to unreasonable expenditures, or the consuming public unduly burdened, because of the unusual or extraordinary demands of one customer."

Pollution control. A cease and desist order has been served by the federal secretary of health, education, and welfare on the city of St. Joseph, Mo., and eighteen meat-packing and other industrial establishments there, to bring to an end the discharge of untreated wastes into the Missouri River. A hearing board appointed under the Federal Water Pollution Control Act found such discharge to be a health hazard and a serious interference with use of the stream in Kansas for public water supply and other purposes. The board held that treatment was practicable and recommended a deadline of Jun. 1, 1963, for completion of facilities.

Reservoir recreational use. The California legislature has passed the "Masterson Bill" establishing a procedure for opening to recreational use

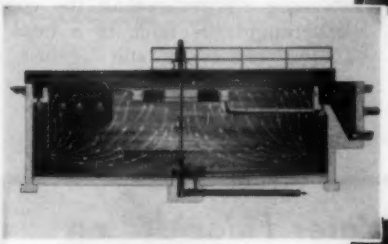
(*Continued on page 62 P&R*)

REX® Water Treatment Equipment



Better Settling. Use of the Rex Verti-Flo Clarifier makes possible improved settling...increases capacities...effects important cost savings.

Better Flocculation. The Rex Floctrol makes possible the production of an optimum floc with the minimum amount of chemicals ...savings in both power and chemical costs.



Better Clarification. Design of Rex Rim-Flo Clarifiers provides increased capacity — maximum efficiency in circular tanks. Entire tank volume is utilized — short-circuiting practically eliminated.

Better Sludge Removal. Rex pioneering in conveyor sludge collector design has led the way to positive, efficient high-capacity removal of sludge from settling tanks...far lower operating and maintenance costs.

Designed for quality...built for performance...

Continuous research and product improvement have long been the guiding principles of CHAIN Belt Company. The important developments illustrated here are but a few of the contributions CHAIN Belt has made toward greater efficiency and economy in the operation of water treatment plants.

A Rex District Sales Engineer will be happy to provide the complete details...or write CHAIN Belt Company, 4609 West Greenfield Avenue, Milwaukee 1, Wis.

CHAIN BELT

(Continued from page 60 P&R)

the reservoirs owned by governmental agencies other than chartered cities. The provisions do not apply to reservoirs holding water that is used for domestic supply without treatment after withdrawal.

A sour legal note was struck by the village of Pawling, N.Y., in settling a contractor's claim for $12,770 for public water supply improvement. It seems that, in the course of clearing an area to enlarge a village-owned reservoir, the work crew inadvertently encroached on the land of a neighboring farm. When the error was discovered, the landowner deeded the piece of property to the village, but, owing to a state law forbidding local governments to construct public improvements on private land, Pawling had to request a special act of the legislature before the contractor could be paid. The name of the generous farmer? Thomas E. Dewey.

Up to their ears in water have been Detroit and its neighboring communities ever since the Wayne County Road Commissioners, at the urging of the Detroit water board, went ahead with design and construction of a $50,000,000 water plant to supply communities throughout the county that are now supplied by Detroit. With a change in administration and outlook, Detroit decided that it could do the job more efficiently than the county and brought the issue to a head by filing a taxpayer's suit against the

(Continued on page 64 P&R)

for Public Water Fluoridation

Sodium Silicofluoride – 99%
(Powder)

Sodium Fluoride – 98%
(Powder or Granular)

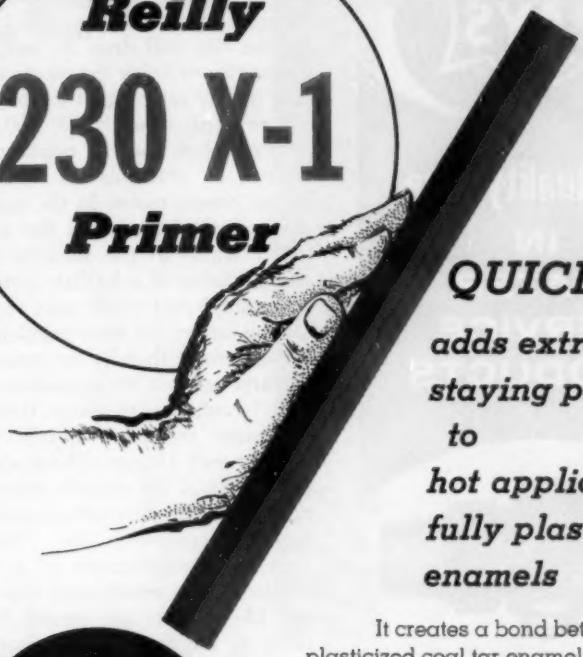
Meet AWWA specifications

White or tinted blue • Dry and free-flowing
Minimum of storage space • Available in bags and drums
Minimum of dust in handling

THE AMERICAN AGRICULTURAL CHEMICAL COMPANY
100 Church Street, New York 7, N. Y.

AA QUALITY

Reilly 230 X-1 Primer



QUICKLY

adds extra staying power to hot application fully plasticized enamels

It creates a bond between fully plasticized coal tar enamel and metal that strengthens as it serves... that, when properly applied, increases the reliability factor of the application process on steel pipe and tank surfaces to a comfortable 100%.

Reilly 230 X-1 Primer

Reilly 230 X-1 Primer is

1. Quick drying, 20 minutes ± in clean atmosphere at 70°F.
2. Non-sagging and non-curtaining.
3. Economical to use (750 to 1400 sq. ft. gal. coverage).
4. Derived wholly from coal tar materials.
5. Acceptable to A.W.W.A. and government standards.

Specify REILLY 230 A. W. W. A. enamel with 230 X-1 primer. Also, soon to come, HS X-1 for Hot Service and QD-X-1 for Intermediate enamel.

REILLY TAR & CHEMICAL CORPORATION

1615 MERCHANTS BANK BUILDING
11 So. Meridian Street
Indianapolis 4, Indiana

HAYS

the Quality Line
IN
WATER
SERVICE
PRODUCTS

CORPORATION
STOPS

One of a
complete line of
Water Service
Products

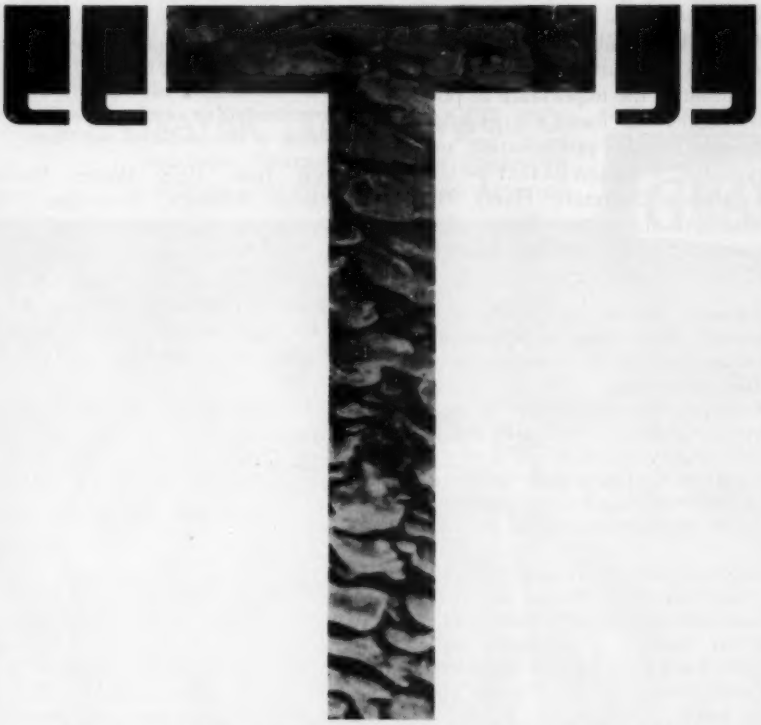
GENERAL PRODUCTS DIVISION
HAYS MFG. CO.
ERIE, PA.

(Continued from page 62 P&R)

county which effectively blocked completion of the new system. Now, under an agreement finally approved on Jul. 30, the city will drop its suit, permit the county to finish the plant, and then take it over on completion, paying the county approximately $58,000,000 for the new plant and the existing county system of transmission mains. A strong consideration in the agreement has been the expectation that adequate feeder mains to the suburbs and the strengthening of suburban systems can be accomplished much more rapidly by Detroit under the lease-purchase-operate agreement than by the county, particularly against the opposition of Detroit. And, as if to assure the support of county residents, a July drought brought such a surge of lawn sprinkling that fifteen of the suburbs were practically dry and many others sustained a noticeable pressure dip. Thus, not even the announcement of a rate increase to both county and city averaging 13–15 cents per month had any effect as the county supervisors voted 81 to 3 in favor of the deal. All this, we understand, had absolutely nothing to do with the news, broadcast throughout the nation on Aug. 24, that the basement of Gerald Remus, superintendent of the water board, had been flooded the night before. And as proof that peace has been restored, he wasn't even accused of hoarding.

Freese, Nichols, Turner & Collie, Houston, Tex., engineering firm, has announced the withdrawal of two Fort Worth members, Simon W. Freese and Marvin C. Nichols. The Houston firm will continue under the name of Turner & Collie, while the Fort Worth firm will practice as Freese, Nichols & Endress.

(Continued on page 66 P&R)



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(Continued from page 64 P&R)

Wisconsin Water Works Week, Sep. 20–26, brought still another official recognition of the importance of public water supply and those who supply it. Our copy of the proclamation came unexplained, but from its text we know that Section Secretary Harry Breimeister and the other officers of the Wisconsin Section had an important hand in promoting it:

WHEREAS, almost two-thirds of the population of the State of Wisconsin is dependent upon public water supplies for its daily needs; and

WHEREAS, the availability of potable water is essential to the health and welfare of our citizens; and

WHEREAS, the maintenance of adequate water distribution facilities is essential to the safety and economic life of our State; and

WHEREAS, the Wisconsin Section of the American Water Works Association, through many persons of management and technical capacity, is constantly extending its efforts toward water conservation and improvement of water works operations; and

WHEREAS, it is of public interest for our citizens and civic leaders to become acquainted with and support planned water works development:

Now, therefore, I, Gaylord A. Nelson, Governor of the State of Wisconsin, do hereby proclaim the week of September 20 to 26, 1959, as WISCONSIN WATER WORKS WEEK and request all citizens to join with me in paying tribute to the public water utilities and associated personnel for contributing so much to the life and well-being of the people of our State.

With June 1958 Water Works Month in Missouri, November 1958 Water Works Month in West Virginia, 1959 Water Works Year in Illinois, and Jul. 12–17 Water Works Week in San Francisco leading up to this, we hope we see a trend toward more good times acoming.

G. R. Herzik Jr. has been named director of the Div. of Sanitary Engineering, Texas Dept. of Health, replacing the late V. M. Ehlers. Herzik has been with the department since 1937.

Bernard S. Bush, regional sanitary engineer of the Pennsylvania Dept. of Health, died Aug. 4, 1959, at Wilkes-Barre, Pa. He was 60. Born in Bear Creek, Pa., in 1899, he held a B.S. in mechanical engineering from Pennsylvania State College. He joined the health department in 1927 as an assistant in the engineering bureau of the Wilkes-Barre office, and advanced through several promotions until named district (now regional) sanitary engineer in 1940. He was widely known

(Continued on page 98 P&R)

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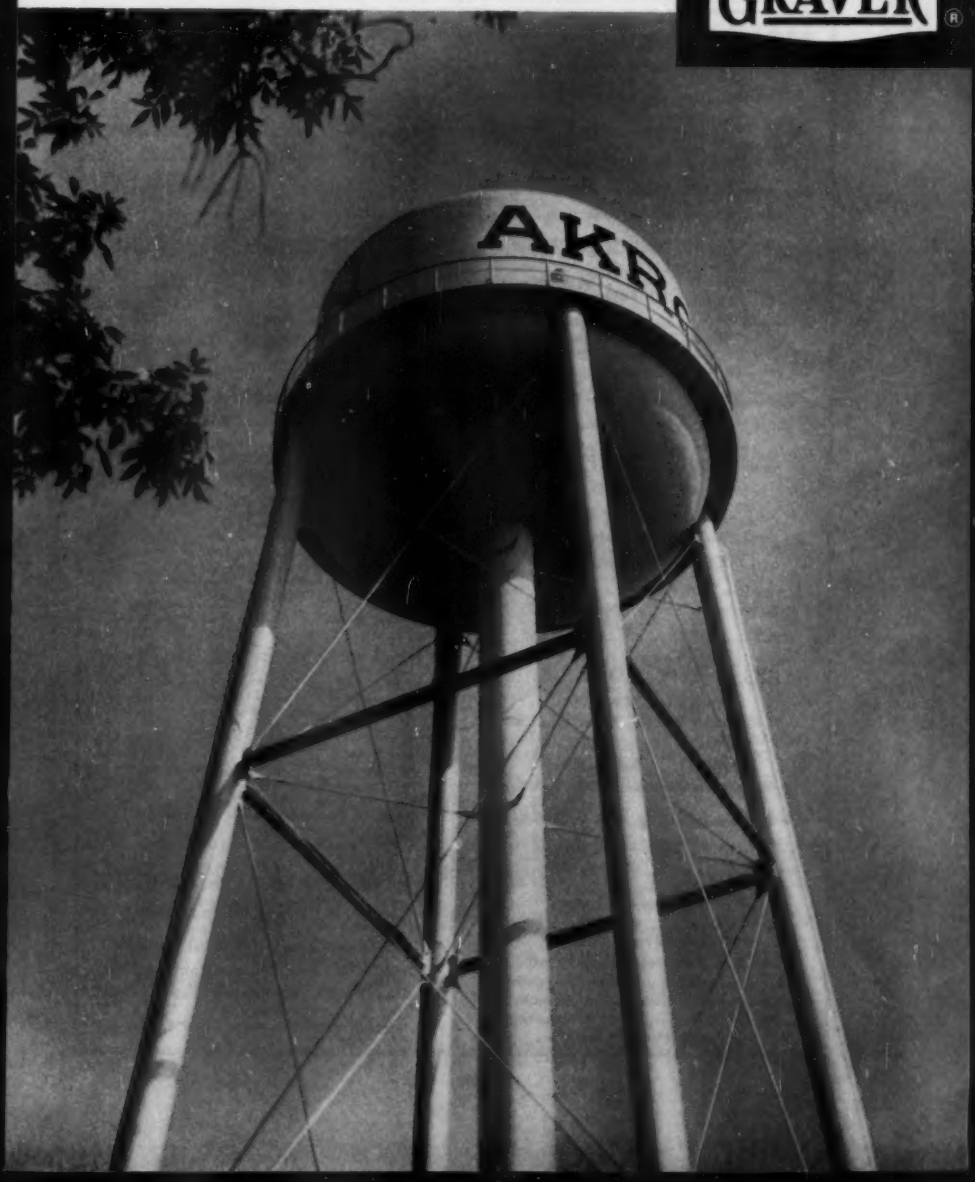

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SALINE WATER CONVERSION

Practical Methods for the Purification of Saline and Brackish Waters. J. R. EMMETT. Proc. Soc. Water Treatment & Examn., **6**:90 ('57). Distillation of sea water is practical in arid regions devoid of other sources of water. Installed and projected world-wide plant capacity is 15 mgd. Overall cost of such water is high, being approximately $1.80 per 1,000 gal for large installations. It will be somewhat less where free fuel is available or where power generation can be combined under favorable conditions with water production. Problems of scale formation have been largely overcome. Methods of reducing scale formation are discussed at some length. Electrodialyses process is not at present economically competitive with distillation for sea water, but it appears to be suitable for brackish waters contg. not more than 10,000 ppm tot. solids. Experience with operating installations is needed to evaluate its potentialities properly. —*PHEA*

Saline Water Conversion. J. L. GILLMAN. Chem. Eng. Progr., **53**:12:68 ('57). At an international symposium on saline water conversion held in Washington, D.C., in Nov. '57, reports were presented on research on demineralization of sea water being carried out in a no. of different countries. Recommendations concerning future work on demineralization by distillation, electrodialysis, solar distillation, and freezing were put forward.—*WPA*

Demineralization of Sea Water. K. FISCHBECK. Chim. & Ind. (Paris), **79**:563 ('58). Author describes methods for demineralization of sea water, including evapn., crystallization, liquid-liquid extraction, ion exchange, electrodialysis, and osmosis. Technical and economic aspects of various methods are considered, and a bibliography of 39 references is appended.—*WPA*

Saline Water Conversion.—Proceedings of a Symposium, Nov. 4–6, 1957. Nat. Acad. Sci.—Nat. Research Council Publication 568 ('58). At a symposium on saline water conversion, sponsored jointly by the Office of Saline Water of the US Dept. of Interior and the US National Academy of Sciences —National Research Council, and held in Washington, D.C., 45 papers were presented by various authors. Papers are grouped in following sections: [1] saline water conversion activity; [2] distillation methods; [3] solar distillation methods and equip.; [4] electrodialysis, membrane, and osmosis processes; [5] freezing processes; and [6] other developments and applications. A bibliography of 321 references is appended.—*WPA*

Saline Water Conversion by Freezing. H. M. HENDRICKSON. Refrig. Eng., **66**:31 (Aug. '58). Battelle Technical Review, **7**: 721a (Nov. '58). A program to investigate existing commercial freezing equipment, to develop a practical freezing-melting cycle, and to predict costs is described.—*PHEA*

Use of Ion Exchangers for Treatment of Salt Water. E. V. SHTANNIKOV. Uzbek. Khim. Zhur., Akad. Nauk Uzbek. S.S.R., 1:15 ('58). Tests on synthetic and natural mineral waters show that ion-exchange resins Espatit-I and EDE-10 can make the hard H_2O of Central Asia potable.—*CA*

Griffin-Raleigh Water De-ionizer. Lab. Practice (Lond.), **7**:697 ('58). An illustrated description is given on Griffin-Raleigh deionizer, for demineralization of water. Principle of apparatus is based on fact that a mixt. of 3 resins improves sepn. of resins before regeneration and makes it possible to regenerate small columns *in situ*. Results of

(*Continued on page 78 P&R*)

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(*Continued from page 76 P&R*)

tests using apparatus to demineralize water from various cities are given, and costs of operation are indicated.—*WPA*

Ion Exchange. R. KUNIN; F. X. MCGARVEY; & D. ZOBIAN. Ind. Eng. Chem., **50**:458 ('58). This review of recent publications on ion exchange contains references to theory of ion exchange and preparation of ion-exchange resins, to studies on selective ion-exchange membranes, and to work on design of ion-exchange units and applications of ion exchange, including treatment of boiler feedwater, demineralization of brackish water, and treatment of trade waste waters such as radioactive waste waters and plating waste waters. A bibliography of 175 references is appended.—*WPA*

Evaporation. W. L. BADGER & R. A. LINDSAY. Ind. Eng. Chem., **50**:438 ('58). This review of recent publications on evapn. includes a brief discussion on developments concerning theory and heat transfer coefficients; evaporative cooling; the problem of scale, with special reference to the evaporators used to provide demineralized water from sea water; and various special processes, including evapn. of sea water and of spent sulfite liquor. A bibliography of 50 references is appended.—*WPA*

Some Aspects of Water Supply With Particular Reference to Sea Water Distillation and the Weir "Multiflash" Plant Ordered by the States of Guernsey Water Board. J. C. BRYAN. Water & Water Eng., **62**:483 ('58). A 0.5-mgd salt water reclamation plant will be commissioned in 1960. This process uses a multiple-stage flash evapn. effect which results in a saving in amt. of heating surfaces. By combination of water reclamation and elec. power production, it is expected that costs of water produced by this process will be competitive with that of some catchment reservoir schemes.—*CA*

(*Continued on page 82 P&R*)

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(Continued from page 78 P&R)

An Introduction to Solar Distillation. T. DE JONG. Proc. ASCE, J. San. Eng. Div., **84**:1704 (Jul. '58). This paper presents a study and results of expts. on production of potable water with solar energy on 3 pilot plants in Iran. Effects of geographical location, size and shape of plants, descriptions of various plants and methods of distillation, on actual production of pilot plants are explained.—*PHEA*

Electrodialytic Demineralization. E. WEGELIN. TNO Nieuws (Neth.), **13**:154 ('58). Author outlines principles of demineralization by electrodialysis, and reviews development of process at Netherlands Centraal Technisch Instituut T.N.O. Costs of demineralization of different types of saline water are shown in a table.—*WPA*

Scaling Problems in Electrodialysis With Permselective Membranes. B. A. COOKE. Chem. & Ind., III ('58). Probs. caused by formation of scale during pilot plant studies on electrodialysis for demineralization of ground water from gold mines in Orange Free State, S. Africa, are described. Selective semipermeable membranes prepared from parchment were used in a multicell arrangement and it was found that a ppt. of barium and strontium sulfates, insoluble in acids, was deposited on the cathode side of each cationic membrane after continuous operation. When polarity of cell was reversed, deposit adhered only loosely, and was easily removed by flushing. Another cell was therefore installed, in which polarity was reversed regularly, and after a long period of continuous operation, it was shown that no scale accumulated. Gelatinous sludge which formed in cathode compartment after rinsing with untreated mine water, could be removed by treatment with acid, and it was found that by reversing the polarity of the cell, sludge was dissolved by acid formed in anode compartment. Magnesium hydroxide or calcium carbonate scales, which are acid soluble and may contain silica, form on anode side of anionic membrane, and are also removed by reversal of polarity of cell. It is concluded that reversing polarity of a cell provides an effective method for removal of scale, and further work on subject is at present in progress. This method of descaling is easy to apply in a continuous electrodialysis process, and is to be incorporated in the new plant being constructed for the demineralization of water in an Orange Free State gold mine.—*WPA*

City Orders Saline-Water Plant. Eng. News-Record, **160**:23:23 ('58). A 28,000-gpd electric-membrane demineralization plant is planned to treat brackish well water at Coalinga, Calif., to replace drinking and cooking water supply at present brought by rail from Armona, 45 mi away. Plant consists of a no. of membrane "stacks," each of which can treat 20 gpm, with 40–50% removal of dissolved solids. 2 stacks in series can remove 65–75% of salts. It is planned to operate 4 of stacks in series in order to reduce dissolved solids content of water from 2000 ppm to a max. of 300 ppm, which is well within required limits. A separate distribution system will continue to supply undemineralized brackish water for purposes other than drinking and cooking.—*WPA*

FLUORIDATION

Studies in Uniformity of Fluoride Ion Levels in a Fluoridated Public Water Supply, City of Rahway, N.J. W. H. AAROE. Public Health News, **39**:359 (Dec. '58). Purpose of study was to investigate truth of claims by opponents of fluoridation that [1] present feeders and methods are incapable of providing consistent fluoride levels in water delivered by public supplies and [2] periodically excessive fluoride concns. are released into water from accumulations of deposits in distribution systems. It was found that in Rahway, N.J., neither of these claims was true. Despite the varying fluoride levels in different sources of water, 88% of samples of delivered water tested within 0.1 ppm of avg. of 1.1 ppm. There were no significant differences in fluoride levels in samples taken from dead ends, smaller users, and heavy users.—*PHEA*

Connection Between the Mineral Content of Drinking Water and the Biological Effectiveness of the Fluorine in It. V. A. KNIZHNIKOV. Gigiena i Sanit. (USSR), **24**:4:71 ('59). Hardness of water does not affect biol. effectiveness of F, but there is a loss of F in boiling both as volatile substances and as ppts. This occurs more in hard water and is rather variable and may

(Continued on page 84 P&R)

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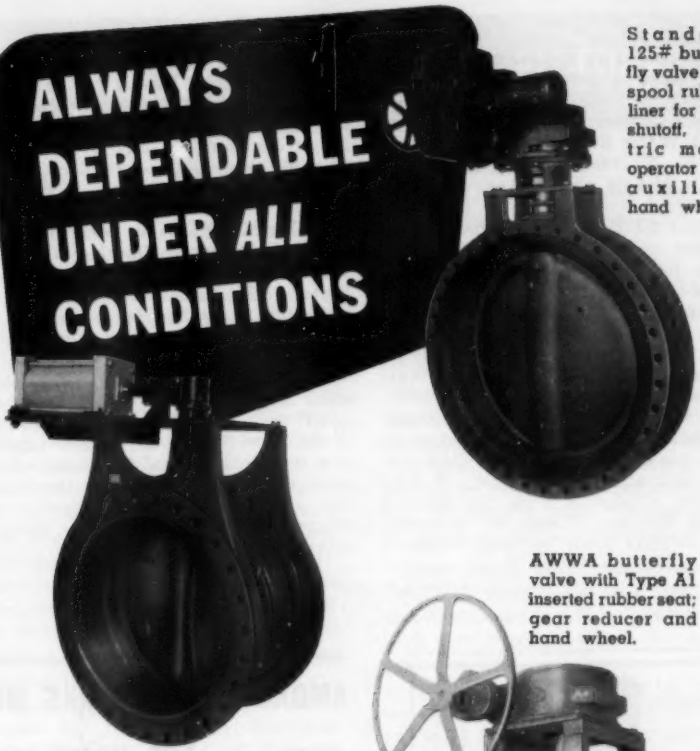

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(*Continued from page 82 P&R*)

account for some of the variations in biol. response found in popn.—*CA*

Fluoride Content of the Uzbekistan (USSR) Water Supply. A. Z. ZAKHIDOV & V. E. NAZYROVA. Gigiena i Sanit. (USSR), **24**:5:64 ('59). Avg. content of F^- in mg/l in surface water is 0.5–0.7, in well waters 0.3–0.5 except in some parts of Samarkand and Fergana districts where up to 2.6 is found, and in drinking water of Tashkent 0.1–0.3. Children of Tashkent have many dental caries.—*CA*

Investigations on the Fluorine Supply of Humans. S. GERICKE. Literaturber. Wasser, Abwasser, Luft & Boden, **7**:9 ('58). Detn. of fluorine in 1 day's food of 20 different adults showed that it contained on an avg. 0.52 mg of fluorine, 80% of which was in solid food and 20% in liquid. If daily requirement is taken as 1 mg, this shows a deficit of fluorine. Expts. on increasing fluorine in plant foods by using fertilizers contg. fluorine showed that this had no effect. A correct balance can be obtained by using water contg. fluorine; a content of 1 mg/l in water supply is required to give daily requirement of 1 mg. Fluorine content of water supply is therefore of great importance, especially for children.—*WPA*

Pathological Studies in Man After Prolonged Ingestion of Fluoride in Drinking Water. E. F. GEEVER, ET AL. Pub. Health Repts., **73**:721 (Aug. '58). Part two of a series, this report describes microscopic findings in bones from persons coming to necropsy who had lived 10 yr or more in communities with naturally occurring or added fluoride in the drinking water compared to a control group. Bones were examd. from 37 persons exposed to 1.0–4.0 ppm fluoride and from 33 persons who resided in essentially nonfluoride communities. The microscopic examn. disclosed no significant differences that could be related to fluoride intake.—*PHEA*

(*Continued on page 86 P&R*)

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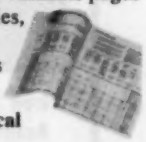

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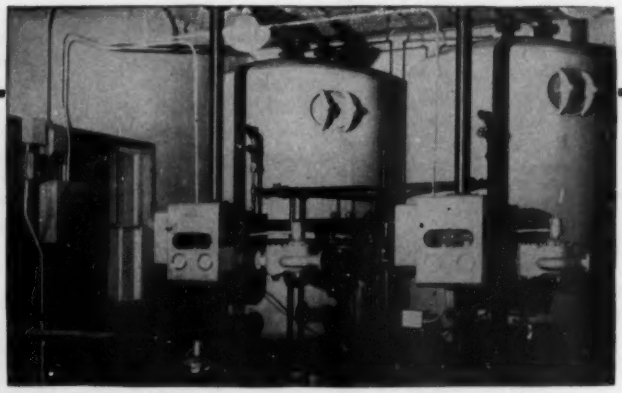
(*Continued from page 84 P&R*)

Incipient Fluorine Intoxication From Drinking Water. G. L. WALDBOTT. Acta Med. Scandinavica, **156**:3:157 ('56). In severe fluorosis changes in bones and joints occur in advanced stage of disease, but author is convinced that an intake of fluorine which is insufficient to produce these changes may, nevertheless, be responsible for ". . . backache, numbness and pain in legs and arms, especially the ulnar area, gastro-intestinal and bladder disturbances as well as ulcers in the mouth and visual disturbances. Most impressive are extreme malaise and mental sluggishness. Two unusual phenomena may perhaps be considered pathognomonic as they probably occur in no other disease; the more water the patient drinks, the more he complains of dryness in the mouth and throat. . . . Exhaustion is most pronounced when the patient should feel most rested, namely, in the morning after resting all night." Waldbott considers that there may be a highly individual susceptibility to fluorine—factors linked with increased susceptibility being malnutrition, old age, sex, dietary habits, additional exposure to fluorides through inhalation, absence of protective minerals (calcium and phosphorus) in food and water. Waldbott sent out a questionnaire to be completed in respect of patients who appeared to be affected by this disease. He gives a table showing the systems and organs affected in 52 patients, but there are no particulars regarding the fluoride concn. in the drinking water. In his summary he merely says that fluoride-containing drinking water in concns. around 1 ppm accounts for a characteristic clinical syndrome.—*BH*

Fluoride Deposition in Human Bones After Prolonged Ingestion of Fluoride in Drinking Water. I. ZIPKIN, ET AL. Pub. Health Repts., **73**:732 (Aug. '58). Essentially same bones studied by Geever and associates (above) were analyzed for ash and fluoride. Analysis of rib, iliac crest, vertebra, and sternum indicated that concn. of fluoride in bones increased linearly with

(*Continued on page 88 P&R*)



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(Continued from page 86 P&R)

increase of fluoride in drinking water up to 4.0 ppm.—*PHEA*

Fluorine in Human Bone Related to Age and the Water Supply of Different Regions. D. JACKSON & S. M. WEIDMANN. Pathol. & Bacteriol. (Gr. Br.), 76:2:451 ('58). Authors ascertained fluorine content of normal human bone (6th rib) in order to discover how far it may be influenced by variations in dose of fluorine and time of exposure. They chose 3 regions of England with substantial differences in the fluorine content of the drinking water: [1] Leeds—water containing virtually no fluorine (42 specimens); [2] S. Shields—water supply containing at present 0.8 ppm (27 specimens); [3] W. Hartlepool—water supply containing 1.9 ppm (56 specimens). S. Shields figure is lower than that of 10 yr ago because of recent addns. of moorland water supplies. In Leeds there was a steady increase in fluorine uptake from age of 12–40 yr, after which rate of increase lessened until a plateau was reached at age of 55. Equilibrium is reached when fluorine content approximates to 190 mg per 100 g bone. In S. Shields there was an identical pattern of fluorine uptake, plateau being reached at age 50–60, with a fluorine content only 25% greater than Leeds plateau figure. In W. Hartlepool, plateau was reached at about 55 yr of age, but fluorine content approximated to 400 mg per 100 g bone—a level twice as high as that found in Leeds. It might be expected that as Leeds water contains practically no fluorine there would be no appreciable increase of bone fluorine in Leeds as age advances, but authors' findings show that even in absence of waterborne fluorine there is at least a 10-fold increase in bone fluorine in Leeds between ages of 13 and 50 yr. It is possible that there is some other source of fluorine, and authors suggest that this source is probably tea leaves.—*BH*

(Continued on page 90 P&R)

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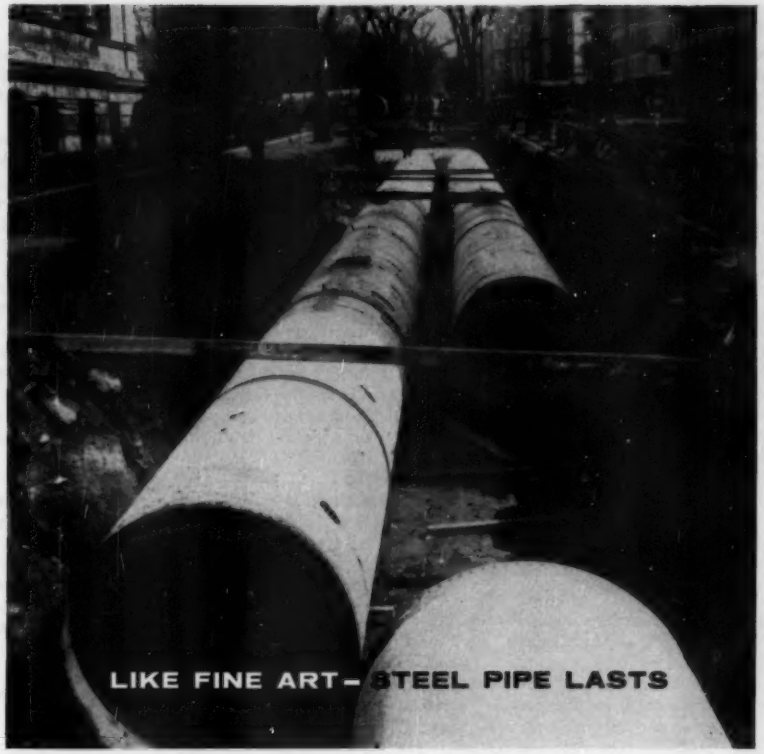

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(Continued from page 88 P&R)

Environmental Public Health Services. Some Modern Aspects of Water Supply. R. C. HOATHER. Med. Press, p. 488 (May 20, '57). This is 9th of a series of articles to be published at monthly intervals under the general title of "Environmental Public Health Services." It deals in general outline with some modern aspects of water supply. Classical waterborne diseases have been almost completely elimd. in Gr. Br., where approximately 95% of pop. is served with piped water supply. Article then gives short consideration to rivers as sources of water supply, tastes, and traces of heavy metals in water. Nitrates in relation to methaemoglobinaemia in infants and radioactive substances are mentioned. Much of article is devoted to review of distribution of fluoride in natural waters of Britain, but discussion of controversy over addition of fluoride to water supplies was deliberately omitted. Bibliography includes some reports of committees on special subjects and 2 textbooks valuable for general reference. —*BH*

Methods of Fluoridation of Water. C. R. Cox. Rev. Obras. Sanit. Nacion (B. Aires), 39:97 ('57). Following aspects of fluoridation of water supplies are discussed: occurrence of fluorine in natural waters; removal of fluorine from natural waters; quant. of fluorine compds. required and methods and effects of fluoridating water supplies; toxicity of fluorine with reference to effect of excessive doses in water; other methods of administering fluorine to pop.; comparison of fluorine compds. for use in fluoridation of water; supply of chems. and costs of fluoridation; protection of operators by avoidance of powder formation; administration; and lab. control. Practical efficiency of process is illustrated by reference to its application in Newburgh-Kingston, N.Y., and comparison of results of this 9-yr treatment as regards occurrence of dental caries, with similar results in Aurora, Ill., where water naturally contains 1.2 ppm fluorine.—*WPA*

A System for Fluoridating Individual Water Supplies. F. J. MAIER. Am. J. Public Health, 48:717 ('58). Need for fluoridating individual water supplies in rural areas is discussed, and device which has been used to fluoridate well water at 4 homes in suburban area of Md. for 2 yr is described. Device enables automatic accurate addition of minute quantities of fluoride to water without risk of overdosage. 2 types of feeder are described and shown diagrammatically, solenoid-actuated diaphragm feeder, and water pressure-actuated diaphragm feeder. They are designed for use with electrically driven well pumps which discharge into a pressure tank. Most satisfactory fluoridating compd. was found to be magnesium silicofluoride. Timing devices are wired into pressure switches so that feeders operate only when pumps are working. Device generally operated satisfactorily, but expert maintenance is required. Provision of this fluoridating service by organizations such as local health depts., with or without simultaneous chlorination, is also discussed.—*WPA*

Latest Results of Fluoridation of Water Supply for Prevention of Caries in Part of Kassel (Ger.). H. HORNUNG. Staedtehygiene, 9:26 ('58). Water supply of a section of Kassel has been treated with fluorides since end of 1952. Author gives latest results of examn. of teeth of children in 2 schools, 1 in this section and control school. He then discusses advantages of method of administering fluorides and replies to arguments which have been raised against it.—*WPA*

Climate and Fluid Intake. D. J. GALAGAN, ET AL. Pub. Health Repts., 72:484 ('57). Study was carried out by USPHS and Contra Costa County (Calif.) Health Department to investigate relationship between climate and fluid intake, as this is of importance in detg. optimum concn. of fluoride to be added to water supply. This was done by measuring actual amts. of fluid consumed by large no. of children exposed to varying climatic conditions. Antioch and Brentwood, in Contra Costa County, were selected as study sites. Records of fluid intake for 450 Antioch and Brentwood children from infancy up to 10 yr of age were obtained during 39 5-day observation periods in a period of 1 yr. Detailed temp. and humidity data were also obtained throughout yr. Results of study are given in tables. It is thought unlikely that humidity (80%) has any influence on fluid intake among children. Total fluid intake per lb of body

(Continued on page 94 P&R)

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These ads offer a free booklet telling about the water problem. It shows how responsible citizens can acquaint themselves with the needs of their community. It also gives a step-by-step outline of action, telling how they can help their officials extend and improve the local water system through more adequate rate structures or financing.

Let us send you a free copy of this new booklet. Write to Thos. F. Wolfe, Managing Director, Cast Iron Pipe Research Association, 3440 Prudential Plaza, Chicago 1, Ill.

Three reasons why cast iron pipe is America's greatest water carrier:

1. More miles of underground cast iron water mains are now in use than of all other kinds of pipe combined.

2. More miles of cast iron water mains are now being purchased and laid than of any other kind of pipe.

3. Impartial surveys prove that today's water utility officials and consulting engineers prefer cast iron pipe for underground water distribution by an overwhelming majority.

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE

Reader's

Oh, what will you do without water?

You mean there's a shortage? Indeed there is. In the last five years over 1000 U. S. communities have had to ration water. It's growing less plentiful all the time. Will you run dry? It depends on you.

Now, what can you do about water?

This free booklet, *"WATER—make sure you'll always have plenty,"* tells how to learn if you're running short, what to do if you are. Write Cast Iron Pipe Research Assn., Prudential Plaza, Chicago 1, Ill.

Printed in your interest by the makers of America's greatest water carrier . . .

CAST IRON PIPE

(Continued from page 90 P&R)

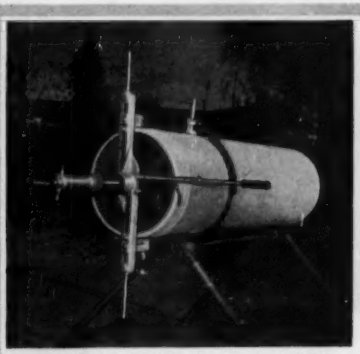
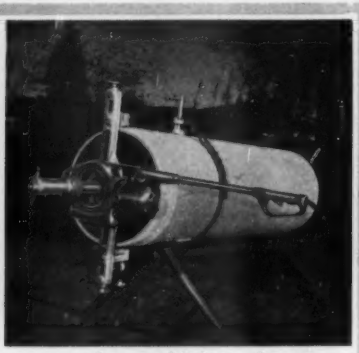
weight is inversely proportional to age and there does not appear to be any sex difference in consumption of fluids. It is concluded, from observations, that water intake is directly prop. to temp. under normal living conditions.—*WPA*

The Problem of Fluoridation of Water Supplies for Prevention of Dental Caries. H. HORNUNG. Arch. Hyg. (Berlin), **141**: 596 ('57). Author discusses efficiency and safety of fluoridation of water supplies and results obtained in Kassel and United States. —*WPA*

Status of Controlled Fluoridation in the United States, 1945–57. Pub. Health Repts., **73**:634 ('58). Data are given on fluoridation of water supplies between 1945 and 1957 inclusive. Tables giving towns with a pop. of 500,000 or more which have installed fluoridation, communities which have installed, reinstalled, or discontinued fluoridation during the 12 yr under consideration, popns. they serve, and legislation; and graphs showing pop. served, and percentage of communities which carry out fluoridation of their water supplies, are included.—*WPA*

Variations in the Concentration of Fluorine in Water Supplies (Belg.). R. BUYDENS. Tech. Sanit. Munic., **53**:181 ('58). Variations in concn. of fluorine in water from different sources which are used for supply in Belgium are discussed, and phys. and chem. changes which bring about and result from these variations, are described. Examples are given of effect on humans of an increase in concn. of naturally occurring fluorine over optimum dose, in Flanders, Belgium, special attention being paid to occurrence of dental caries in children. In Audenarde, Flanders, 2 sources of water supply are used, one from wells and other from springs; spring water contains 0.15 mg/l, and well water 5 mg/l of fluorine, and both were previously regarded as satis-

(Continued on page 96 P&R)

PILOT FIELD LATHES save money by machining asbestos-cement pipe right on the job!

Make factory-like ends on any length when and where you need them. No waiting – no delays.

Power or manually operated. All sizes from 4" thru 20".

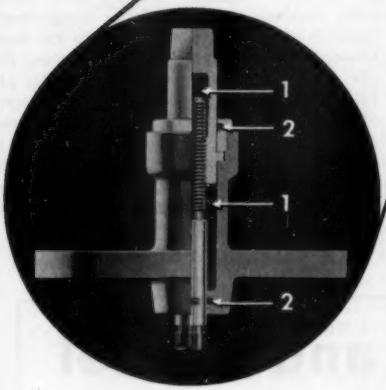
Write for details and name of nearest distributor.

Distributor inquiries invited

PILOT MANUFACTURING COMPANY

P.O. BOX 2127, TORRANCE, CALIFORNIA

WHAT'S INSIDE? A BIG PLUS



Smith Fire Hydrants are easy to operate, inexpensive to maintain and most dependable in meeting severe climate and operating conditions. In addition to maximum flow and simplicity of design, Smith Hydrants now have two additional features of major importance: (1) Automatic lubrication — chamber sealed with "O" Rings contains a permanent type lubricant — temperature range–30° to 200°F. Each time the hydrant is operated, the threads and bearing surfaces are automatically lubricated. (2) "O" Ring Seals — the lower "O" Ring seals the internal pressure, the upper "O" Ring is a combined external dirt and moisture seal. This construction eliminates the conventional stuffing box and packing gland adjustments.

65

FIRE HYDRANTS VALVES SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

(*Continued from page 94 P&R*)

factory source of supply. As a result, many people receive excessive doses of fluorine, and a medical examn. of teeth and health of every person using that water, and an extensive examn. of all water supplies to determine concn. of fluorine are recommended.—*WPA*

The Mitotic Activity of the Epithelium of the Thyroid Gland in Rats Receiving Water Treated With Fluorine. H. R. Muehlemann & R. Schneider. Schweiz. Med. Wochschr., **86**:625 ('56). Treatment of water supplies with fluorine for prevention of caries raises problems of secondary effect of fluorine on thyroid gland and relation between endocrinic function and rate of mitosis. Tests on rats showed administration of fluorine for 1 week had no effect on rate of thyroid cell division.—*WPA*

Pathological Studies on Man After Prolonged Ingestion of Fluoride in Drinking Water. E. F. Geever, et al. Pub. Health Repts., **73**:721 ('58). Microscopic studies were made of bones and lumbar intervertebral body joints from bodies of 37 people who died after residing for at least 10 yr in a district where drinking water contained 1–4 ppm naturally occurring or added fluoride; and similarly, as a control, from 33 subjects who had resided in areas where the water contains less than 0.5 ppm fluoride. Although microscopic changes were observed in bones and joints incidental to aging, these changes were not related to the fluoride intake, and occurred in both groups of subjects. Expts. are claimed to give further evidence that fluoride in drinking water at a level of 1.0 ppm can be ingested without cumulative toxic effect.—*WPA*

Is There a Connection Between Goiter and Fluorosis in Isparta (Turk.)? S. Velicangil & S. Eser. Literaturber. Wasser, Abwasser, Luft & Boden, **7**:8 ('58). Investigations showed that high doses of fluorine had probably no influence on occurrence and development of goiter even in districts in which slight goiter was endemic and water supply contained 4.3 mg/l fluorine. It is thus hardly likely that addns. of 1 mg/l of fluoride would produce or increase goiter. —*WPA*

Defluoridation of Water Supplies. G. G. Cillie; O. O. Hart; & G. J. Stander. J. Inst. Water Engrs., **12**:203 ('58). Lab. expts. and pilot-scale tests using activated superphosphate for defluoridation of water supplies have led to development of large-scale equip. for both continuous and batch defluoridation. Design and operation of equip. are described, including prepn. of ion-exchange column from a hard granular superphosphate. Batch process is particularly suitable for defluoridation of individual household supplies. Column is regenerated with sodium hydroxide. If water supply contains more than 10 ppm fluoride it should be treated with lime before passing it through ion-exchange column. Studies were made, using borehole water supply of horticultural research station at Roodeplaat, 19 mi from Pretoria, to investigate factors affecting the efficiency of the process (including the pH value, addition of carbon dioxide to control pH value at 7.0 or less, interference of chloride ion, and rate of flow of water), to standardize operational processes, and to estimate costs of treatment. A flow sheet and a photograph of defluoridation plant at Roodeplaat are included.—*WPA*

Filter Sand and Gravel

Well Washed and Carefully Graded to Any Specification.
Prompt Shipment in Bulk or in Bags of 100 lb. Each

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P. O. Box 307 **Muscatine, Iowa**

ERP At Work

This quiet scene should not mislead. Electro Rust-Proofing *is* hard at work. There's no hustle or bustle . . . just dependable, continuous cathodic protection.

Underneath this water an ERP-engineered protection system fights rust—fights maintenance costs. The battle was joined before installation. ERP Engineers surveyed the plant . . . designed and installed a system that gives maximum protection at lowest cost. And now ERP Service follows up. Continuous protection is assured . . . maintenance costs are the lowest ever.

If you want to stop trouble before it starts, if you want to protect your investment in steel structures—quietly, efficiently, economically—use Electro Rust-Proofing Systems. ERP is preventive maintenance at work.

We'll be glad to send more information. Write Dept. E-51.05

ERP CATHODIC PROTECTION SINCE 1935

ELECTRO RUST-PROOFING CORP.

A SUBSIDIARY OF WALLACE & TIERNAN INC.

30 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CABLE: ELECTRO, NEWARK, N. J.

(Continued from page 66 P&R)

and respected for his work with municipalities and industries on the state's water pollution abatement program.

An AWWA member since 1954, he also belonged to ASCE, FSIWA (Bedell Award), Pennsylvania Water Works Operators Assn., and Pennsylvania Assn. of Professional Engineers.

Ralph Gumaer, vice-president of Philadelphia Meter Co., a Neptune Meter Co. subsidiary, died Jul. 21, 1959, in Overbrook, Pa. He was 62. Born in Kingston, N.Y., in 1896, he lived for many years in Ardmore, Pa. Mr. Gumaer joined Philadelphia Meter in 1930 and assumed the duties of manager of the Philadelphia office. He was previously employed by Mueller Co., Decatur, Ill. He was active in water industry affairs as a member of AWWA (since 1944), and the Pennsylvania Water Works Operators Assn.

Frederick S. McKay, the dentist whose work with stained teeth led to the practice of fluoridating drinking water, died Aug. 21, 1959, at Colorado Springs, Colo. He was 85. Born in Lawrence, Mass., he was graduated from the University of Pennsylvania Dental School in 1900 and began practicing at Colorado Springs the following year. He soon noted that the teeth of many of his patients showed mottling of the enamel, a condition for which there was no apparent explanation. His interest aroused, he began an investigation which he, and other researchers, carried on for 30 years until fluoride in water was proved to

(Continued on page 100 P&R)

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1. It Costs Money

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Only National Tank Maintenance Corp. "Special-Skil" Applicator crews protect you completely against paint damage. Our crews use a special paint roller—designed and patented for us. Our crews use DRI-MIST long lasting paints. National Tank exclusives . . . "Special-Skill" crews . . . our own design paint roller . . . and special long lasting DRI-MIST paints reduce damage . . . cut cost. You and your community benefit.

Our Engineering Department will furnish an estimate on your water tank without cost or obligation. Write, wire or telephone National Tank.

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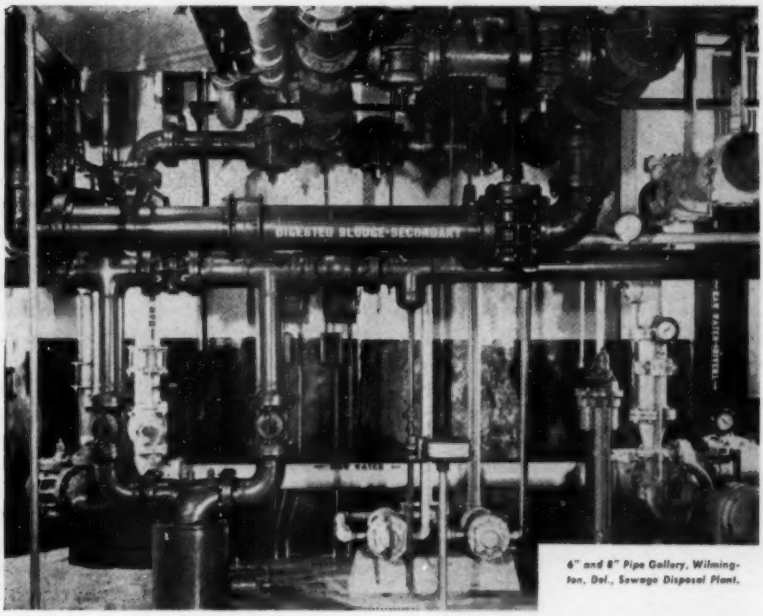
A New Guide to water works facts and figures

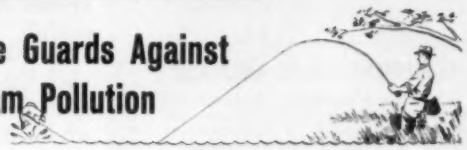
The complete text of "A Survey of Operating Data for Water Works in 1955" with Seidel & Baumann's statistical analysis; combined with Porges' summary of the 1955 USPHS survey of treatment facilities in one handy paperbound book. Journal Reprint R722; $1.25.

American Water Works Assn.
2 Park Ave., New York 16, N. Y.



6" and 8" Pipe Gallery, Wilmington, Del., Sewage Disposal Plant.

Cast Iron Pipe Guards Against Stream Pollution



Every 12 hours a contract is let for a new sewage treatment works to clean up America's waterways and protect the public health.

Into these plants go thousands of tons of enduring cast iron pipe and fittings. Engineers designing these plants know that no other pipe material compares with cast iron in withstanding the corrosive effects of strong sewage, acids and treatment chemicals. And none has equal strength or a matching time-proved record of long life and low cost service.

Engineers also specify large cast iron pipe for sewer force mains to operate under pressure where strength, longevity and a minimum of jointings are a vital factor. So cast iron pipe not only serves to bring water to our cities and towns but takes it away for cleansing treatment and returns it pure for use again.

Our Company does not manufacture cast iron pipe but supplies many of the nation's leading foundries with quality pig iron from which quality pipe is made.

WOODWARD IRON COMPANY

Since 1882

WOODWARD, ALABAMA

(Continued from page 98 P&R)

Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Available

WATER WORKS CHEMIST
or
CHEMICAL ENGINEER

Graduate chemist or chemical engineer wanted to supervise Production, preferably with water works experience and administrative experience in Water Filtration Plant and Hydro-Electric Plant. Salary range commensurate with experience and ability. Send resume, salary requirement, and application to General Manager, Water Works and Hydro-Electric Plant, 310 So. Wapello St., Ottumwa, Iowa.

EQUIPMENT SALES ENGINEER

Unusual and challenging job opportunity in Sales Department of our Equipment Division, specializing in our internationally recognized electric membrane equipment for demineralization of saline water and for other process uses. Our sales have more than trebled since 1955, and we expect that our rate of growth will continue to be among the most rapid in the industry.

We want a man with a college degree and a minimum of five years' selling experience—preferably in heavy equipment or in the water treatment field. The job involves dealing with consulting engineers, industrial scientists, engineers, executives and government officials. Independent judgment, effective written and oral presentations, persistence, unusual energy, and drive are needed. Our sales engineers are based in Cambridge and travel in the U.S. or abroad for up to six months per year—working with local agents and representatives.

A limited number of sales trainees with college degree but from none to five years' experience will also be considered.

Send resume and salary requirements to:
William E. Katz,
Vice President—Sales

IONICS®
INCORPORATED
152 Sixth Street
Cambridge 42, Massachusetts

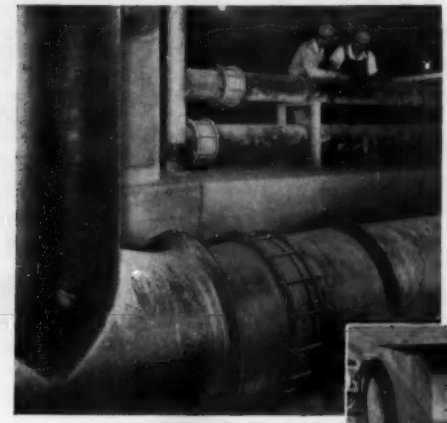
be the cause of the mottling. In the course of these studies, it came to light that mottled-enamel teeth were remarkably free from decay, a fact which suggested that fluoride could be used to reduce dental caries. For his work in this field, Dr. McKay received the Lasker Award from the American Public Health Assn. in 1952.

By unhappy coincidence, Dr. McKay's death came only 3 weeks after the passing of another fluoridation pioneer, William L. Hutton, who, as medical officer of health at Brantford, Ont., was the first such official anywhere to recommend to his city council the application of fluoride to drinking water. Dr. Hutton died Jul. 30, 1959, at the age of 71. He had been Brantford's medical officer for 39 years, until his retirement 8 months previously, and was also internationally known for his work in diphtheria control.

In 1955 both McKay and Hutton were honored at a meeting of the Detroit District Dental Society as men who "shall long be revered in the memories of all who hold that the public good is paramount."

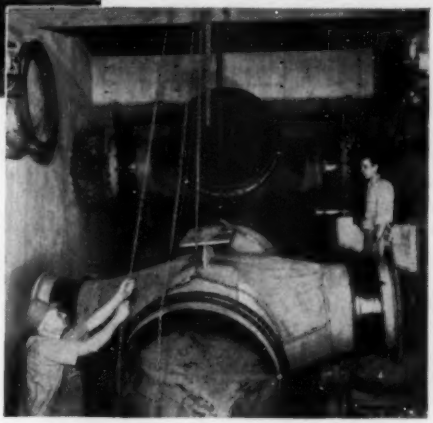
James L. Wheelin, sales representative of Neptune Meter Co., New York, died Jul. 19, 1959, at the age of 59. Mr. Wheelin was with the Thomson Meter Co. when it was purchased by Neptune. He was assistant manager of the service department until 1929, when he joined the Neptune sales department. Born in Brooklyn, N.Y., he served as a district reporter for a local newspaper, the *Eagle,* prior to entering the water industry. His reportorial skills were utilized as the first editor of the *Neptune News,* an internal house organ, which began publication in 1948. He had been an AWWA member since 1947.

Joining pipe the Dresser way...



Always the easy way...

The 8-inch, 10-inch and 30-inch Dresser-Coupled lines illustrated here are part of the system used in servicing the Clague Road's advanced rapid-sand type filters.



often the only way!

This battery of steel crosses is in the new Clague Road Filtration Plant, designed by Havens and Emerson, Cleveland, Ohio. The Plant will carry a normal flow of 50-million gpd. Contractor: Hunkin-Conkey Construction Company.

Dresser® Couplings provide the essential leeway for bolting up cross flanges to valves in tight spots. They'll take deviation caused by settling concrete and remain bottle-tight... permanently! Dresser's vibration-proof properties protect valves and other expensive equipment, and protect the pipelines, too. With a Dresser Coupling, two man-minutes per bolt gives you a permanent, leak-proof joint that absorbs expansion-contraction movement, keeps maintenance problems to a minimum, and makes repairs easier if and when they do become necessary. For a free copy of "Dresser Couplings for Filtration Plant Piping" and the Dresser Sewage Treatment Plants booklet, write to Dresser Manufacturing Division, Bradford, Pennsylvania.

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DRESSER
MANUFACTURING DIVISION

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Correspondence

For Five Drachmas . . .

To the Editor:

Your P&R department is read here with much pleasure and profit. Humor based on putting familiar things in their true (though up to now unsuspected) relationship can get across home-truths that bales of scientific papers merely smother. Long may P&R seep!

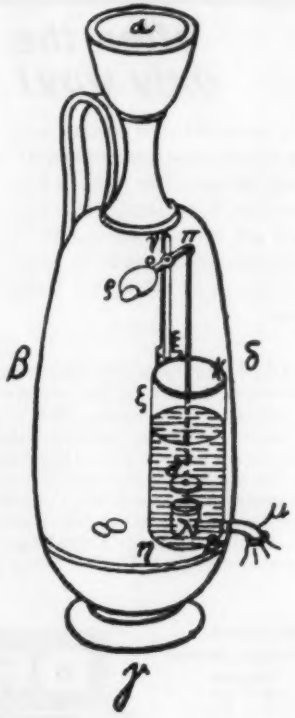
There is, however, one hole in the dike into which, I venture to suggest, a thumb ought to be stuck. October 1958 P&R remarks, p. 35, that, "possibly for lack of coins of small enough denomination, water has not, until recently, been mechanically" vended. I regret to say that this statement is inaccurate. The fact is, coin-fed water-vending machines, invented by Hero of Alexandria, were in use as early as the third century BC. According to *Pneumatica:*

Many vessels for offerings are arranged so that holy water for sprinkling flows out when a five-drachma piece is inserted. Take a libation vessel or a money box [see cut], of which the aperture α is not closed. Let there be in the money box (or the libation vessel) a [small] vessel with water and a box from which an exit tube μ leads outwards. Next to the vessel place a vertical rod, $\nu\xi$, about which another, $o\pi$, rotates like a scale beam. Let $o\pi$ be widened at o into a thin plate which (in the state of rest) lies parallel to the bottom of the vessel. At π attach a small vertical rod, $\pi\sigma$, to which there is attached at σ a lid exactly fitting the cylinder, so that it can interrupt the escape of liquid through μ. Make the lid of the cylinder heavier than the little plate ρ but lighter than the combined weight of the lid and the coin. When the coin has been inserted into the aperture α, it drops into the plate ρ and so, depressing the cross-beam, $o\pi$, brings it into an inclined position while drawing up the lid of the cylinder; as a consequence of this the water is allowed to flow out. So soon as the coin has dropped (from ρ) the lid again closes the box and arrests the flow of the water.

C. F. B. Stevens

Montreal, Que.
Jul. 16, 1959

Reader Stevens is not only nice, but right—the Greeks had a coin for it, though the water involved was sanctified and ours is only sanitized.—Ed.



(*Continued on page 104 P&R*)

MORE THAN 2,000 PRESTRESSED CONCRETE WATER TANKS IN SERVICE

In the development of residential and industrial water supply facilities today, no other type of tank offers so many advantages as does the Prestressed Concrete Tank. Modern in engineering and design, proven in service, lowest in cost... prestressed concrete should be considered in any tank planning.

Check these advantages:

- Minimum maintenance
- Satisfied owners
- 75% of construction cost spent locally
- Lowest overall cost
- Longest service life of any tank

Send for Bulletin T-22

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THE CANADA GUNITE COMPANY, LTD.
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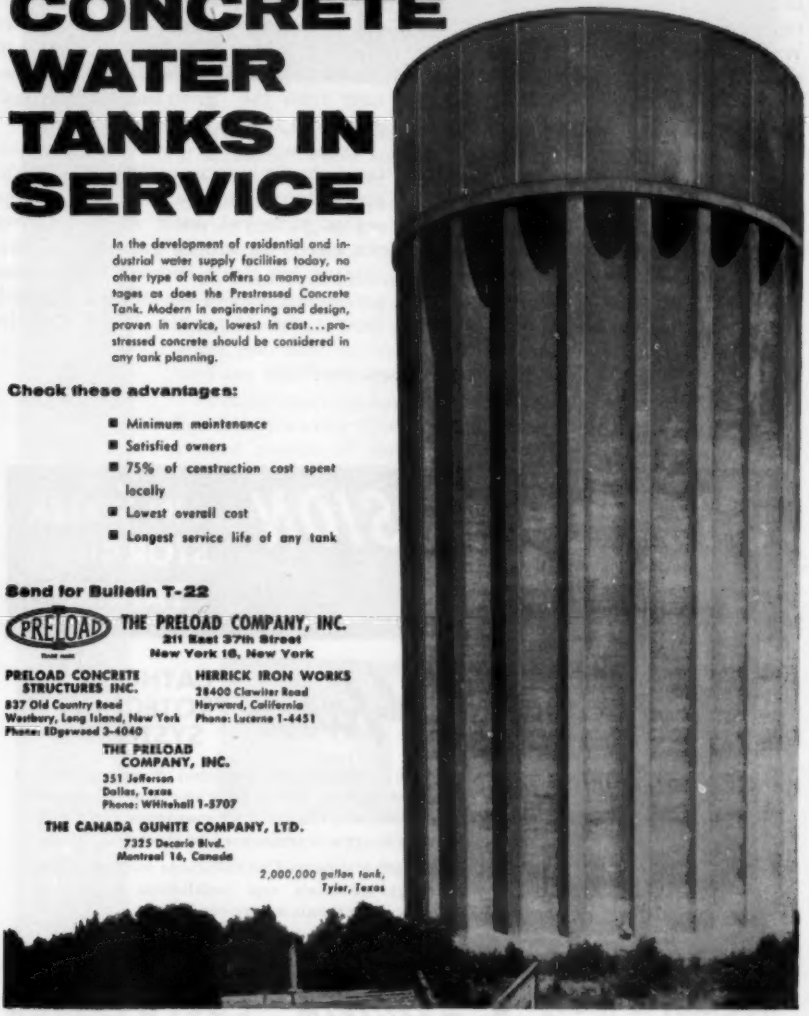
Montreal 16, Canada



2,000,000 gallon tank,
Tyler, Texas

Correspondence

(Continued from page 104 P&R)

AWUA

To the Editor:

Recently, at a hearing before the Public Service Commission of Wisconsin, the representatives of the Milwaukee Water Works were admonished by a commissioner: "You are a public utility. You should act like a public utility."

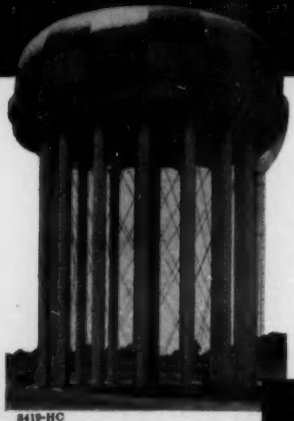
Since then I have been turning the matter over in my mind. We at Milwaukee have never frankly recognized ourselves as a "utility." Our letterhead reads "Milwaukee Water Works." Even the professional association we belong to is named the American Water *Works* Association.

"Works" refers to structures, grounds, machinery, and the like. Such phrases as "gas works" are reminiscent of a bygone era. On the other hand, "public utility" (or, simply, "utility") is defined as "a business organization . . . performing some public service." Our Public Service Commission regards the Milwaukee Water Works as a *proprietary* interest of the city, rendering a "utility service" distinct from the "governmental services" performed by other city departments.

Consequently, we have been considering a change in name to "Milwaukee Water Utility." In line with this concept —that municipal water supply involves not merely structures, grounds, and machinery, but also a business organization performing service—should not AWWA become the "American Water Utilities

(Continued on page 106 P&R)

STOP CORROSION . . . IN WATER STORAGE TANKS



with Harco CATHODIC PROTECTION SYSTEMS

Everyday, electrolytic corrosion damages thousands of dollars worth of water storage tanks. Harco specialists can protect your investment with a cathodic system engineered to meet your needs.

Harco job-engineered installations include tests, drawings, materials, and installation as well as periodic maintenance services.

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Crystal-pure water comes cheaper with Dicalite

Compared with sand filtration systems, diatomite filtration of municipal water supply with Dicalite Filteraids starts you out thousands of dollars ahead. And the records of municipalities now using Dicalite filtration prove that clarity and purity are at least equal to the best that sand can do. Health department records also verify this.

Cost savings start with the smaller space requirements of a filter system using Dicalite – no more than a quarter of the space needed for a sand system of comparable capacity. Make your own estimates of what this could save you in land and building costs.

Cost savings continue with the lower capital investment in a Dicalite-using filter system – 20 to 35% below that of a sand system of comparable capacity. This has been proved, times over, by comparative engineering estimates and construction bids.

Municipalities using Dicalite report lower labor costs with their semi-automatic filter systems. Chemical costs may also be reduced. And there are a number of other advantages in Dicalite filtration, all discussed in Dicalite Bulletin BW-13 – why not write for it, now!

Dependable GLC GREAT LAKES Dicalite FILTERAIDS

DICALITE DEPT. • Great Lakes Carbon Corp.,
612 S. Flower St., Los Angeles 17, Calif.

Name_____

Address_____

City_____ Zone____ State_____

Correspondence

(Continued from page 106 P&R)

Association"? This question might well be one for the Board of Directors to consider.

ARTHUR RYNDERS
Superintendent, Milwaukee Water Works
Milwaukee, Wis.; Aug. 5, 1959

Not only is "utility" the word, but we suspect that Friend Rynders is what the Journal would call "manager" of the Milwaukee Water Utility, terminology to which we have been trying to stick for the past couple of years. But AWUA has always seemed one step too far—sort of like kicking one's parents in the teeth. And if we agreed to kick, we would like to come up the something better than A-W-U-A; AGUA or AQUA, at least. But how do other readers react to giving the works to "works"?

GIVE
THE
UNITED
WAY...

through your
UNITED FUND or
COMMUNITY CHEST

UNITED

help more people...
save more lives...

Service Lines

Metal packings for pumps, engines, and compressors are described in a new 24-page booklet. Complete with detailed illustrations, the bulletin contains data for correct selection, application, and installation of metal packing. Bulletin AD-166 is available from The Garlock Packing Co., 438 Main St., Palmyra, N.Y.

Mobile radio is the subject of a 4-page folder that describes a compact, two-way, VHF-FM communications system. The new radio unit features a 6-, 12-, and 115-v power supply. Information on the Aerotron Model 6N15 may be obtained from Aeronautical Electronics, Inc., Box 6527, Raleigh, N.C.

Automatic controls are featured in a 28-page booklet that consists of various magazine article reprints, all of which deal with instrumentation as applied to water and sewage treatment. A copy of Booklet D97-2 is available by writing the Product Editor, Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Steel pipe that is electrically welded is introduced in a 12-page, illustrated bulletin. With photographs and diagrams, the booklet describes the manufacturing process of this type of pipe and gives examples of some of its applications. The booklet "Electricweld Line Pipe" is available from the Public Relations & Advertising Dept., Jones & Laughlin Steel Corp., 3 Gateway Center, Pittsburgh 30, Pa.

Welding accessories are illustrated and described in a new 12-page booklet. Requests for catalog No. 12 should be sent to Tweco Products, Inc., Box 666, Wichita, Kan.

AMERICAN Fastite® JOINT* CAST IRON PIPE

From its plant location in the heart of the industrial South, as well as from strategically located stocks, the American Cast Iron Pipe Company ships pipe fast!

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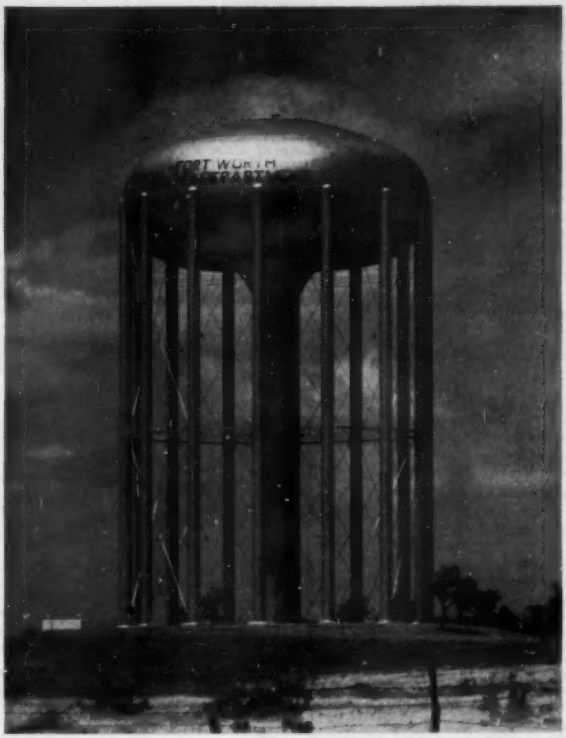

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Installed in 1909 -- Springfield's steel main is still on the job

Things have changed in the waterworks field since '09. But, as the photo shows, even then they were using large-diameter steel pipe in Springfield, Massachusetts.

This 42-in. lockbar steel main carries water some 22,000 ft from Provin Mountain Reservoir in West Springfield across the Connecticut River and into the City. Now in its fiftieth year, it is expected to give many more years of service. And in a half-century it has required very little maintenance.

Another major line, of 54-in. and 48-in. welded steel, with riveted joints, was laid in 1928-1929. It's described as "in excellent shape" today.

The most recent tests indicated the H & W flow coefficients to be 111 for the 1909 line, 140 for the 1928-1929 line, and 143 for another steel line laid in 1949. According to the Municipal Water Works: "These tests showed that steel lines with proper coatings will give very long life as far as carrying capacity is concerned."

Scores of old steel mains are still in service throughout the nation. By present-day standards they were crudely constructed and inadequately protected. If they could give fifty or more years of reliable service, think what today's steel pipe can do—lined and coated with modern coal-tar enamel.

Make your next main a *steel* main. The Bethlehem sales office nearest you will gladly give you full details on the many advantages of steel pipe.

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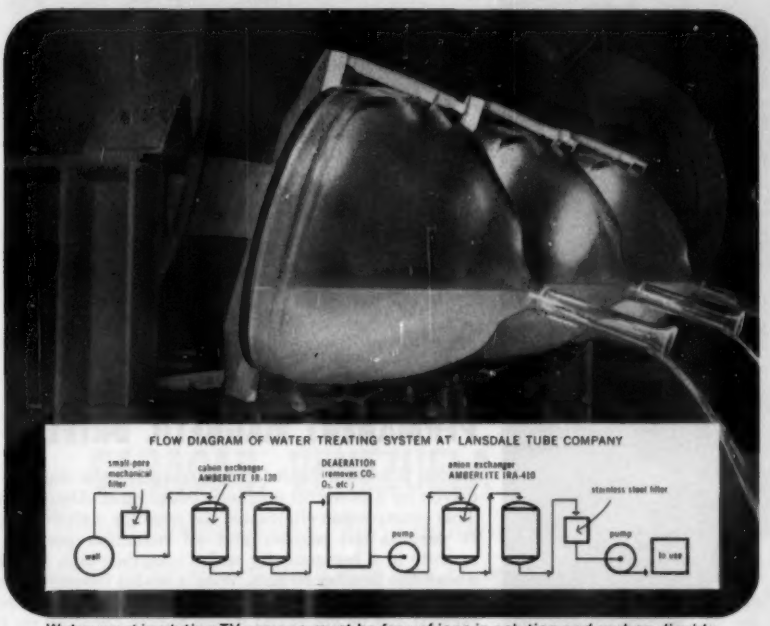
Golden-Anderson Valve Specialty Co
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.
Valves, Regulating:
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co.
Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.
Venturi Tubes:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Wilbur & Williams Co., Inc.
Water Softening Plants; see Softeners
Water Supply Contractors:
Layne & Bowler, Inc.
Water Testing Apparatus:
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.
Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.
Well Drilling Contractors:
Layne & Bowler, Inc.
Well Reconditioning and Formation Testing:
Halliburton Oil Well Cementing Co.
Layne & Bowler, Inc.
Wrenches, Ratchet:
Dresser Mfg. Div.
Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1959 AWWA Directory.

ION EXCHANGE RESINS pave the way for perfect TV pictures



Water used in plating TV screens must be free of ions in solution and carbon dioxide to prevent unwanted reactions and insure a smooth, blemish-free screen.

TV needs 100,000 gallons of AMBERLITE-treated water every day, at Philco's Lansdale Tube Co. Division

Plating the inside of picture tubes calls for water completely free of metallic impurities and carbon dioxide—for washing tubes and preparing phosphor solutions. At Philco's Lansdale Tube Co. Division, the water treating system teams AMBERLITE IR-120 cation exchange resin and AMBERLITE IRA-410 anion exchange resin to rid water of troublesome ions.

Water from the company's well contains 180 ppm hardness, 240 ppm dissolved solids, 150 ppm alkalinity. Deionized and filtered water shows over 600,000 ohm electrical resistance at 18°C. Further deionized water of 20,000,000 ohm resistivity at 18°C. for the manufacture of electronic components is obtained with small MONOBED units containing a mixture of AMBERLITE IR-120 and AMBERLITE IRA-400.

Your engineering company, qualified by experience in water conditioning, can tell you how AMBERLITE ion exchange resins can help you, or—write today for a copy of "If You Use Water".

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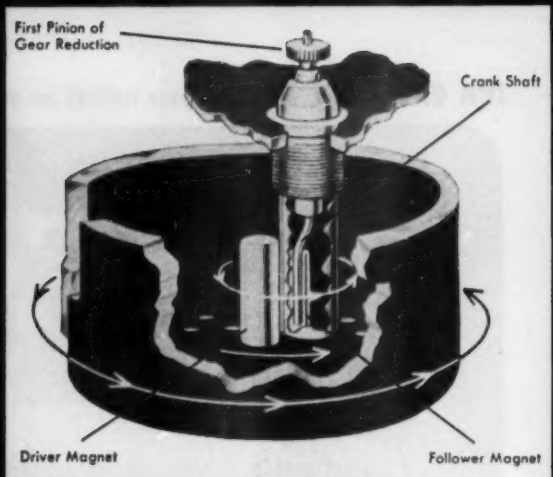
Chemicals for Industry

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.



THE POWERFUL PULL OF A PERMANENT MAGNETIC DRIVE

In the Rockwell Sealed Register meter the register is driven by a powerful magnetic coupling of Alnico alloy. This construction eliminates the need for a stuffing box. It permits the register and all reduction gearing to operate in a hermetically sealed chamber high and dry above the flowing stream. With a sealed barrier against dirt and corrosion, lighter instrument type gears and pinions can be employed which reduce the drag on the measuring chamber and thereby improve meter accuracy and response.

The magnetic drive itself is fully shielded to prevent "cheating." And its powerful magnetic force is good for a lifetime of operation. For descriptive bulletin write Rockwell Manufacturing Co., Pittsburgh 8, Pa.

Now available in both 5/8" and full 3/4" sizes

SEALED REGISTER METERS

another fine product by

ROCKWELL

La Mariposa Water Treatment Plant: Dorrco Monorakes in rear basins; Flocculators in foreground.

CARACAS, VENEZUELA

Dorr Monorakes, Flocculators Boost Capacity

Caracas, with a population over one million and rated one of the world's fastest growing cities, recently completed a second addition to its La Mariposa Water Treatment Plant to increase capacity from 16 to 80 MGD.

The original plant was equipped with two Dorrco Squarex Clarifiers, 115′ square by 14′ s.w.d., and two Type "T" Flocculator units for basins 115′ long by 40′ wide by 11′ s.w.d.

To achieve the five-fold boost in capacity, Dorr-Oliver equipment was again chosen. The recent additions comprise three Type "A" Dorrco Monorakes for basins 202′ long by 65′ wide by 14′ deep, three Type "T" Dorrco Flocculators 50′ long by 65′ wide by 11′ deep, and twelve new Filters.

DESIGN ENGINEERS: Instituto Nacional de Obras Sanitarias.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment.

Squarex, Dorrco—T.M. Reg. U.S. Pat. Off.

DORR-OLIVER

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

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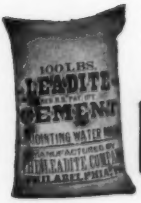
Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%



THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking